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IRRIGATION IN FLORIDA.

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HISTORY OF IRRIGATION IN FLORIDA.

The first attempts at irrigation on an extensive scale in Florida seem to have been made during the droughts of 1890 to 1893. Before that time the production of citrus crops was not highly systematized and little attention was paid to the intensive methods of agriculture which have developed rapidly in recent years.

Prior to the disastrous freeze of 1894–95 the center of the citrus industry was Marion County. The town of Citra was the largest shipping point in the State. Approximately 2,200 acres of orange groves had been planted in this section by 1894, of which about 500 acres were irrigated.

The freeze of February, 1895, followed a very severe one which occurred the preceding December. These two cold spells froze trees to the ground in nearly all the citrus sections of the State and were especially severe in Marion County. The blow to the citrus industry was so great that many of the farmers left the State, while the

majority of those who remained in the industry moved farther south, where the danger from extreme cold is not so serious. The financial depression that followed the freeze caused the abandonment of practically all the irrigation systems, and many of the owners took up the pipe and sold it for old iron. Only about 25 or 30 acres of irrigated groves remain in this section at present.

In the southern counties, where the effects of the freeze were not so disastrous (although very severe), the trees were cultivated and cared for and soon were bearing fruit. The period following the freeze was so favored with rainfall that most of the irrigation systems fell into disuse and many were taken up.

The excessive drought of 1906 revived interest in irrigation, however, and when this was followed by four more dry years many of the most skeptical installed irrigation plants.

The comparatively rainy seasons of the last three or four years have discouraged recent extensive development of irrigation in citrus groves, but the large development of the trucking industry has brought about a considerable extension of irrigation in that field.

ESTIMATE OF TOTAL IRRIGATED CROPS.

An accurate estimate of the total acreage of irrigated lands in the State is difficult to make. Many of the irrigation plants are miles from any others, while some of the territory containing a considerable percentage of irrigated lands would have to be surveyed very carefully to secure any accurate estimate.

Several methods were employed to secure a rough estimate of the acreage irrigated. Much of the State was covered by the writer in an automobile and estimates for each locality were obtained from the best-informed residents. Another source of information was several hundred inquiry cards sent out by the Department of Agriculture and returned by farmers who were practicing irrigation. These cards afforded a good index to the methods and costs of irrigation in the various sections, but were of little use as a general census, since only a small percentage of the plants was reported in this way. Valuable information was obtained from several of the prominent irrigation supply men of the State and from well-known irrigators, who gave estimates of local irrigated areas.

The acreages irrigated are estimated as follows:

Acreage of irrigated crops in Florida in 1915.

	Acres.
Irrigated truck crops:	
Surface irrigated	12,000
Subirrigated	2,500
Overhead spray	3,000
Irrigated citrus groves	8,000
Total	25,500

This estimate probably is fairly accurate and amounts to approximately 10 per cent of the area in grove and truck crops, the area in field crops being of small importance from an irrigation standpoint. Nearly 20 per cent of the truck crops is irrigated, as the total acreage of truck crops in the State is estimated at 91,000 acres. If watermelons and cantaloupes are not included in truck crops, approximately 25 per cent of the present acreage of truck crops is under irrigation.

The largest area of surface-irrigated lands within a restricted district lies in and near the Hastings potato section and equals about 10,000 acres. The remainder of the surface-irrigated lands is scattered, although there are about 1,000 acres irrigated in Manatee County, all within a few miles of the town of Palmetto. The next largest irrigated area is the Sanford district, which contains 1,600 to 2,000 acres of subirrigated lands. The irrigated groves are well scattered over the citrus section, the largest area within a restricted district being near Palmetto, Manatee County. The overhead-spray systems also are well distributed, although there are several trucking sections which contain several hundred acres under spray. The sections around Williston in Levy County, Bushnell in Sumter County, and Bartow in Polk County are the best known.

THE NEED OF IRRIGATION IN FLORIDA.

The condition making irrigation necessary in Florida is not the deficiency in annual rainfall, but its uneven distribution. Localities having a very heavy total rainfall are subject to heavy downpours at times, with long, rainless periods at other times. As crops are grown throughout the year, the distribution of the rainfall becomes of great importance. Truck crops are grown during the winter months—October to May—and require water during that period. Citrus fruits make their growth during the spring and summer months and must not be allowed to become too dry.

The mean annual rainfall at some of the Florida stations is as follows:

Rainfall in Florida.

	Inches.
Pensacola	56.25
St. Augustine	47.98
Orlando	51.02
Tampa	53.21
Fort Myers	52.19
Hypoluxo	63.20

These stations read from north to south, the two extremes, Pensacola and Hypoluxo, having the heaviest rainfall. The central portion of the State from St. Augustine to Tampa varies but little in total

annual rainfall, although its distribution varies considerably, as will be shown later. The distribution of the rainfall and the occurrence of droughts at various points in the State are shown by the accompanying diagrams (figs. 1–4). These charts are plotted from records kept by the United States Weather Bureau from 1892 to 1914, inclusive. The stations selected probably are as representative of the

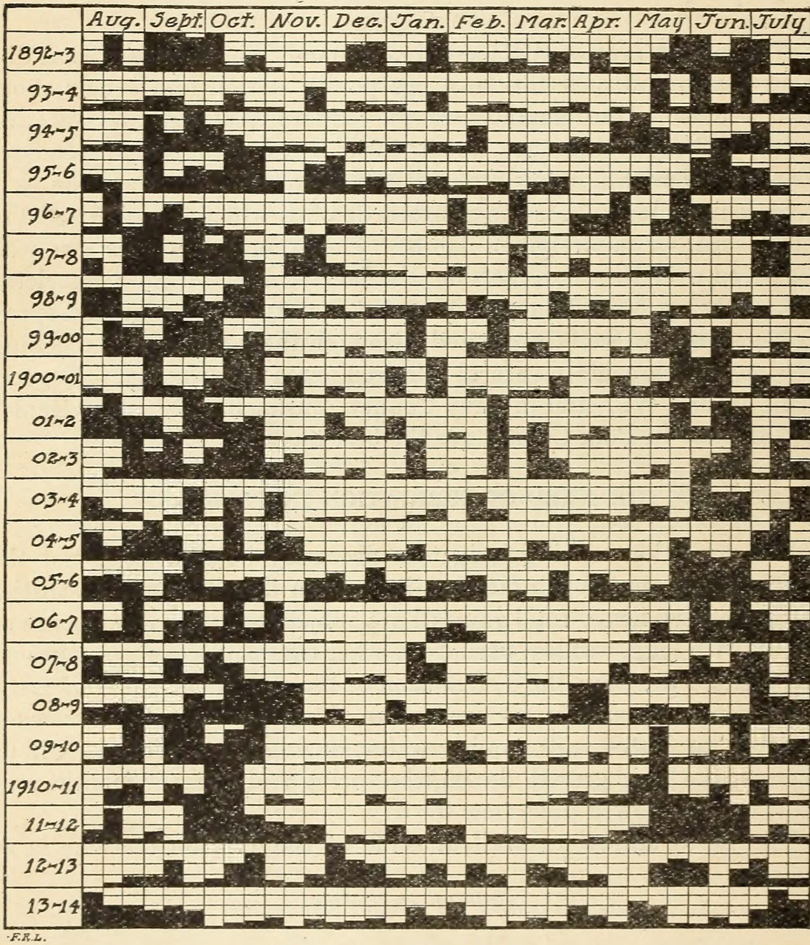

FIG. 1.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892–1914, at Hypoluxo, Fla.

State as any that can be chosen without plotting a great number of points. Thus Pensacola is representative of the northwest counties, Orlando is fairly representative of the central peninsula section, Fort Myers should represent the southern west-coast section, and Hypoluxo the southern east-coast section.

It will be noticed on the charts that the spaces between vertical lines represent 10-day periods, while the black columns between these

lines represent the total rainfall during these periods, up to 4 inches. Many 10-day periods had more than 4 inches of rainfall, but the charts were made to show periods of rainfall rather than downpours. In general, the rainy years show a preponderance of black spaces and the dry years a preponderance of white spaces.

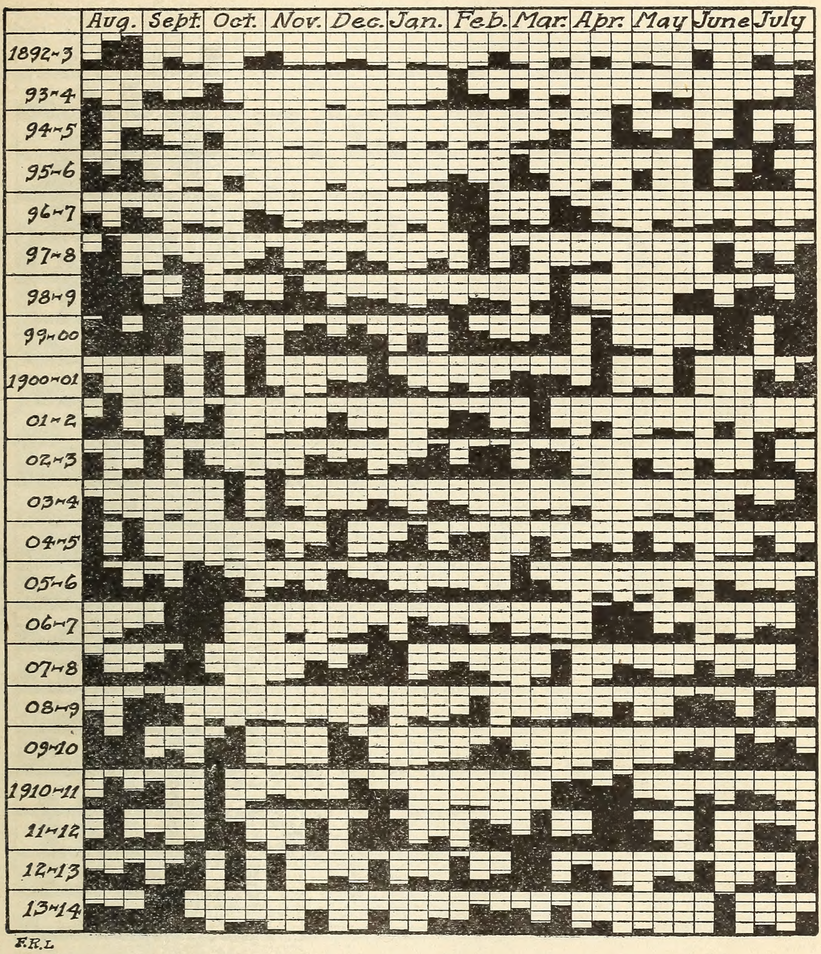

FIG. 2.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892–1914, at Pensacola, Fla.

The Hypoluxo chart (fig. 1) shows heavy rainfall in the summer months although that district is liable to long and severe droughts. Many of the black spaces in this chart represent considerably more

NOTE.—Although the rainfall charts do not indicate each shower the cumulative rainfall for each 10-day period totalling less than 4 inches can be read to within one-fifth of an inch; for example, see the Pensacola chart (fig. 2). The month of September, 1893, shows 1.8 inches rainfall the first 10 days; 1.0-inch the second 10-day period; and 1.2 inches the last period, or a total of 3 inches for the month. It will be seen that no rain fell in November of the same year and 4 inches or more fell in the first 10 days of February, 1894.

than 4 inches, and in some cases as much as 20 inches, of rain within a 10-day period. Hypoluxo is much more subject to these heavy downpours than are the other sections represented, although nearly every part of the State is exposed to excessive rainfall at some period of the year. These downpours usually take place from

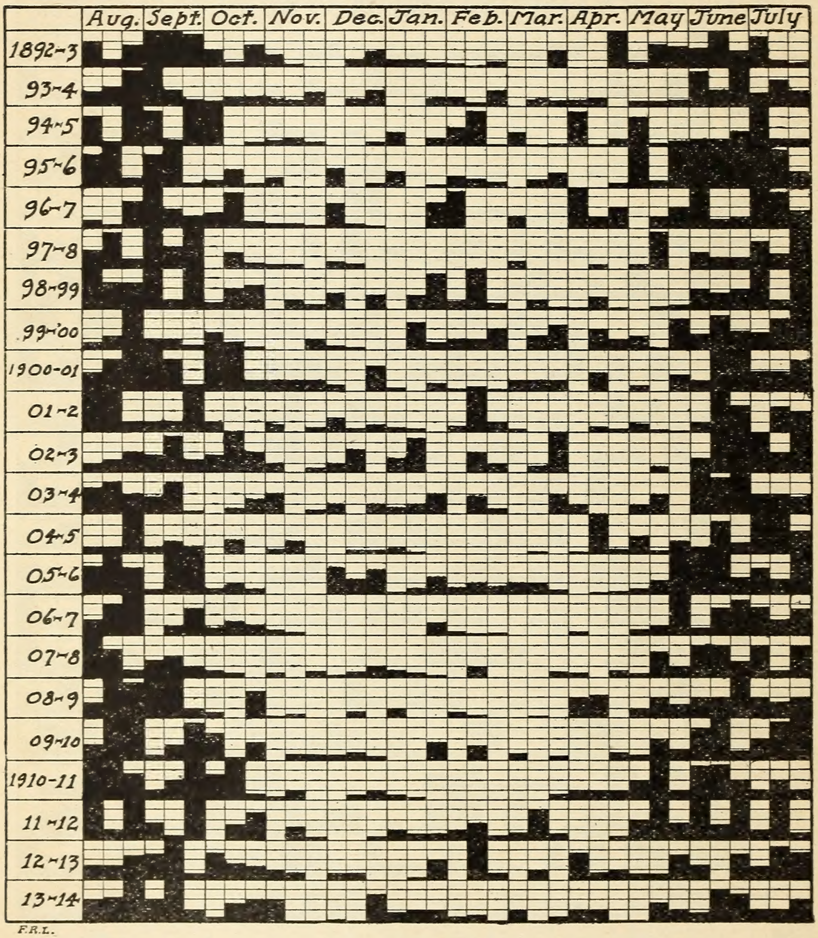

FIG. 3.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892–1914, at Fort Myers, Fla.

June to October, October being the most subject to floods. Floods occur occasionally, however, in the winter and spring months and are apt to do much harm.

It will be noticed that the first great drought shown in the three charts (figs. 1, 3, and 4) representing the southern stations occurred in the season 1897–98. Fort Myers (see fig. 3) shows only light showers from the middle of October to the middle of May, while the

Orlando chart (fig. 4) shows very dry weather from the middle of October until the middle of July. The next drought of State-wide importance occurred in 1906–7, nine years after the one just mentioned. Fort Myers shows only small showers from the middle of

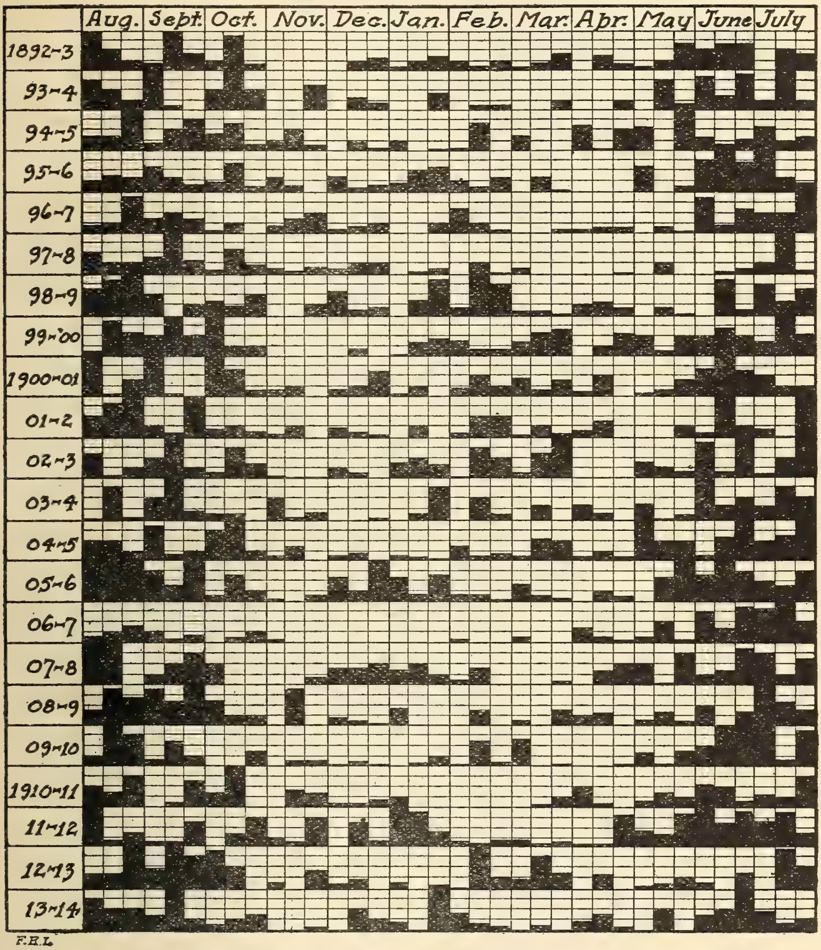

Fig. 4.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892–1914, at Orlando, Fla.

September to the middle of May, a period of nine months. The Orlando chart shows dry weather from the first of August until the middle of June. The small rainfall shown in the charts for the spring and summer months for these years is not enough to be of lasting benefit, as the heat usually is excessive during these long droughts. The same drought, it will be noticed, occurred in Hypoluxo (see fig. 1) although much less severe, lasting from the first of

November to the middle of May. While there is seen to be a little rain in January and February, it presumably was not of lasting benefit.

The two droughts shown above are remembered throughout the State. It is asserted by the older residents that during both of them pine trees died from lack of water, and many of these dead trees are still standing as monuments to dry weather. The effect on the citrus industry also was serious. Although but few of the older trees were killed, nearly all lost their leaves and spring bloom; but orange and grapefruit trees have wonderful recuperative powers. When they have lost all their young fruit in the spring, they often will put forth a late bloom in June and mature this crop the next season. This is called the "June bloom" throughout the State, and is very common when heavy June rains follow a dry spring. The fruit from the June bloom often is inferior in quality and not so marketable.

There is a vast difference between the citrus crops and the truck crops in their need for water. The character of the soil enters largely into this difference and will be discussed in detail later. The average truck crop can not stand a drought of even short duration without serious loss. It is a common sight to see truck farmers irrigating their crops three or four days after a good rain, and in most cases truck crops are irrigated a dozen times before a citrus grove is considered in actual need of water.

Working in cooperation with the irrigation investigations of the Department of Agriculture, a vegetable grower of Hypoluxo has kept records of irrigation and rainfall from 1909 to 1913. His plant is fitted with a meter which records the exact amount of water used. His records also show the dates of each irrigation and the separate amounts of water used. The dates are now of interest in examination of the rainfall chart of Hypoluxo. (Fig. 1.) The amounts of water will be taken up under another heading.

The soil is sandy and representative of much of the sandy hammock along the coast and through other parts of Florida. The plants watered were mostly peppers and eggplant, although at times other crops were raised on the same ground. The soil may be taken as representative of much of the trucking soil of the State.

The season of 1909–10, although dry, as shown by the chart, was not excessively so, yet it was necessary to water the plants twenty times, as follows: twice in October, three times in November, twice in March, ten times in April, and three times in May. The early irrigations were for the benefit of the young settings, which needed water often. The spring irrigations were made to keep the plants in a flourishing condition, as peppers and eggplant bear continuously throughout the season if well cared for. It was necessary to irrigate only

nine times during the season of 1910–11, although it appears to have been as droughty as the previous season. This may have been due to a difference in the cropping, of which there is no record. There were three irrigations in October, three in January, two in February, and one in April. The season 1911–12 appears fairly well supplied with rainfall, judging from the chart, yet the plot was irrigated fifteen times as follows: five times in December, twice in February, five times in April, and three times in May. Fifteen irrigations were necessary in the season of 1912–13, as follows: three in October, one in November, one in December, three in January, two in February, three in April, and two in May. There are no records available for the last two years shown on the rainfall chart, but it is likely that fifteen irrigations, which is an average of the previous four years, would not be too high in either case.

Further study of these records will show that irrigation for truck crops may be practiced throughout every month in the growing season if there is a short period of dry weather, some of the irrigations apparently occurring even at the time of heavy rainfall. This may be due to the fact that several of the irrigations may have been made on successive days preceding a heavy rainfall, or the rainfall may have come in a number of small showers and been of little benefit to the plants. Examination of the entire chart would lead to the conclusion that Hypoluxo's rainfall was such as to call for 10 to 15 irrigations per year for truck crops for the last 22 years. If this is the case it can be seen readily that even more irrigation would be needed in Orlando and Fort Myers, assuming that the same crops were grown on the same type of soil. As a matter of fact, much of the sandy soil around Orlando calls for more water than does the soil around Hypoluxo, while some other crops require more water than do peppers and eggplant. On the other hand, many of the soils which are growing truck are lower and heavier than on this farm, and such truck crops as cabbage and melons need little water.

For citrus groves the dates of past irrigations are difficult to obtain, as no reliable data are at hand covering a long period. However, some records concerning an irrigated grove at Orlando are available and extend from the spring of 1909 to the fall of 1913. This plant was not completed until April, 1909, at which time the leaves of the trees were curling from lack of water. The grove was irrigated four times the year the plant was completed, once each in April, May, June, and July. The rainfall chart shows that water should have been applied several times before April, and the owner reports that he could have saved a great quantity of fruit if he had been ready to irrigate in February. This grove was irrigated once

in 1910 and twice in 1911, these irrigations coming in April and May. There was no irrigation in 1912, and the chart shows that probably none was needed. The years 1913 and 1914 were very well supplied with rainfall, although irrigation should have been practiced in the late spring of both years, and probably would have been if the engine had been in repair. The spring of 1913 was very dry in some parts of the State and was the cause of much loss through dropping of the newly formed fruit.

From a study of the records of the Florida State Horticultural Society,[1] it seems that there was considerable loss from drought in citrus groves in 1892–93 and 1893–94, and again in 1897–98. The proceedings of this society for the years 1895–96 and 1898–99 seem to be barren of discussion regarding irrigation affairs, but interest was again aroused during the long drought of 1906–7 and has continued to the present time, although the last three seasons have been favorable in some sections. A study of the rainfall charts makes apparent the reason for the ebb and flow of interest in irrigation.

Judging from the data in hand and a study of the rainfall charts, it would seem fair to estimate that about half the years (from 10 to 11 years in the last 22) are deficient in rainfall to such an extent as to make irrigation of citrus groves profitable. The Hypoluxo chart shows that the number of years in which irrigation was required is less than this average, probably varying from 5 to 7 in the last 22; in other words, 20 to 35 per cent of the years would call for irrigation. On the other hand, the number of years when irrigation was necessary is not of main consideration. The important points are how badly the trees need water when the dry years appear, and how much damage a drought causes, not only in immediate loss of fruit, but in permanent harm to the tree. These questions are answered in several ways, but nearly all answers agree that such years as 1897–98, 1906–7, and 1909–10 severely shock the health of the tree, and there is no doubt that irrigation at these times would insure a good crop of fruit when prices are high because of the lack of high-grade products.

RELATION OF SOIL TYPES TO IRRIGATION.

The relation of soil types to irrigation probably ranks second in importance to rainfall in determining irrigation needs. The writer has made a number of soil-moisture tests which bear directly on the needs of irrigation, but before discussing this subject it would be well to outline briefly the general types of soils as popularly known.

It is estimated by the State geologist, E. H. Sellards, that 75 per cent of the State originally was covered with pine forests. This

[1] Annual Proceedings of Florida State Horticultural Society.

accounts for the common use in Florida of the term "pine lands." While a large part of the original forests still stands, and there are many thousands of acres of uncultivated "cut-over" or stump lands, there are also thousands of acres of pine lands cultivated for all kinds of crops.

The rolling, or high pine lands, are very extensive, especially in the interior of the State. This land is used for the growing of citrus fruits as it is usually well drained, which seems to be necessary to the successful growth of most of the citrus fruits.

Associated with the high pine lands are the so-called high hammock lands, which differ from the high pine lands in that they bore originally a more or less dense growth of hardwood or deciduous trees. These types of lands usually have a deep topsoil underlain with a clay subsoil at a depth of from 4 to 6 feet, varying with the locality. The upper 6 inches of much of this soil is very dark in color, owing to organic matter, while the soil from the first foot to the clay appears to be almost pure sand, the organic matter decreasing rapidly with the depth. It is very necessary to bear this in mind in accounting for the behavior of water when irrigation by furrow methods is attempted.

Several types of pine lands locally designated under the general name of "flatwoods" are quite extensive in area. The two types best known, the "palmetto" and the "open," generally are very level, with poor natural drainage. The palmetto flatwoods originally were covered with pine and a dense undergrowth of saw palmetto. This type of land invariably has a hardpan underlying the surface at depths varying from 1 foot to 4 feet, and averaging about 2 feet. The open flatwoods may or may not have this hardpan.

These flatwood soils are very important from an irrigation standpoint, being used extensively in both the Hastings and Sanford districts for growing crops under irrigation. The part that this type of soil plays in irrigation will be taken up later.

Although the types of land described above cover the greater part of the State, several other types are cultivated and must be considered in a discussion of irrigation methods. The most noted exception to the sandy soils is the rocky soil of the lower east coast. This section is important in both trucking and citrus growing, although the soil is so rocky in some localities near Miami that large sums are expended in clearing away the rock, and trees frequently are set out in blasted holes. This rock is a limestone formation and forms a rim between the Everglades and the Atlantic Ocean.

Within the Everglades, at the southern end of the peninsula, there is a great area of peat and muck land. It has been estimated that there is between 2,000,000 and 4,000,000 acres. The depth of the

organic material varies from almost nothing to 14 feet, with the greatest depth in the lands adjacent to Lake Okeechobee in the central part of the glades. This area may be of importance from an irrigation standpoint after the drainage works are completed, but until that time little authentic information will be available. However, considerable areas of the Everglades are cultivated at the present time in narrow strips along the canals which have been constructed, and some of this land has been irrigated by both overhead-spray and surface methods. The light organic material dries out quite rapidly if the water plane is lowered sufficiently.

The State also includes a large acreage of muck lands along many of the large rivers and adjacent to the lakes. Only a small part of this land has been drained artificially and used for cultivation, although there are considerable areas under cultivation in isolated spots, as, for instance, along the St. Johns River in the Sanford district, and along the shores of Lake Apopka in Orange County. Probably the largest single drainage project in muck soils, excluding the Everglades, is at Felsmere, a few miles west of the Atlantic Ocean.

A type of soil closely allied to the muck soils is the so-called low hammock or "cabbage-palmetto hammock" lands.[1] These lands usually are very rich and require more or less drainage. Throughout the State many of the best trucking sections are located on this type of land. This soil may or may not be underlain with hardpan.

It will be noted that the few main types of soil discussed above are widely different in their characteristics. In these differences should be found one explanation for the diversified methods used in applying water to the crops. If the surface soil is very loose and sandy, as often is the case with the high pine lands, where the hardpan or clay stratum is well below the surface, the soil moisture probably will percolate below the root area. On the other hand, in the flatwoods where the hardpan is too close to the surface the soil has very little storage capacity, will flood easily, and in time of dry weather, will dry out rapidly. It is claimed by expert orange growers that a hardpan at a depth of 5 to 7 feet is the best condition for the growing of citrus fruits, while a hardpan at a depth of 2 to 3 feet often is regarded as an ideal condition for trucking. Although this is generally true, there are some very fine orange groves on the flatwood type of lands, and there are large acreages of citrus fruits in Lee and De Soto Counties, while many acres of truck are grown on the high pine and high hammock types of soil. Numerous fine groves and truck gardens flourish on the low hammock types all through the peninsula.

[1] The "cabbage-palmetto hammock" lands derived their name from the fact that their original growth contained a preponderance of cabbage palmetto, although there usually is a very dense undergrowth associated with the palmetto.

SOIL-MOISTURE TESTS.

The writer has made a number of soil-moisture determinations in citrus groves in and near Orlando and in the trucking sections of Sanford and Orlando. These tests were made in the spring of 1913 and throughout the season of 1913–14 for the purpose of determining the amount and location of available soil moisture at different times of the year and in the different types of soil.

Figure 5 represents the percentage of soil moisture [1] for the different dates throughout the season 1913–14, and at the same time shows the amounts of rainfall by three-day periods during the season. The tests for this chart were made in a citrus grove in Orlando. The top curve shows the average percentage of soil moisture for the first 6 feet of soil in an open, cultivated space that is not affected either by tree roots or by grass. The lower curve shows moisture content among full-grown orange trees, which have grown up from roots since the 1895 freeze. The vertical figures represent soil moisture in percentages and inches of rainfall, given in three-day periods. As an example illustrating the use of the chart, it will be noted that the total rainfall for the period between January 21 and January 24 was 3.8 inches. Again, note the effect of this rain on the soil moisture. On January 15 the soil in the grove showed only 3.9 per cent of soil moisture and the open space showed about 5.7 per cent. Immediately after the rain the average moisture content for the two sections was 9.5 per cent and 7.8 per cent, respectively, falling to 5 and 5.7 per cent within a few days. It will be noticed that in all cases showing a plentiful rainfall the two curves are close together, but that where the rainfall is deficient the curve representing the soil-moisture content in the grove drops very rapidly. The moisture in the open, rootless space, however, averages considerably higher at all times. The lower curve shows very plainly the effect of tree roots in absorbing the available soil moisture.

It is not possible to determine the exact percentage of soil moisture needed to keep the trees in good condition, as the citrus tree is very hardy and will not show wilt for a considerable period after the available moisture of the soil has been exhausted. The character of the soil also affects this, as some soils are more retentive of moisture than others. But there can be no doubt that the available supply of moisture is gone when the soil will run from the hand like dry sugar. This condition is found in most of the soils tested after the moisture content has fallen below 3 per cent. Judging from the curves in the

[1] The percentages of moisture referred to in this discussion are based on the ratio of the weight of dried samples to the difference in weight between the wet and dried samples. Each sample represents the moisture content at a certain depth in the grove or garden, and this is taken to be representative of a larger area.

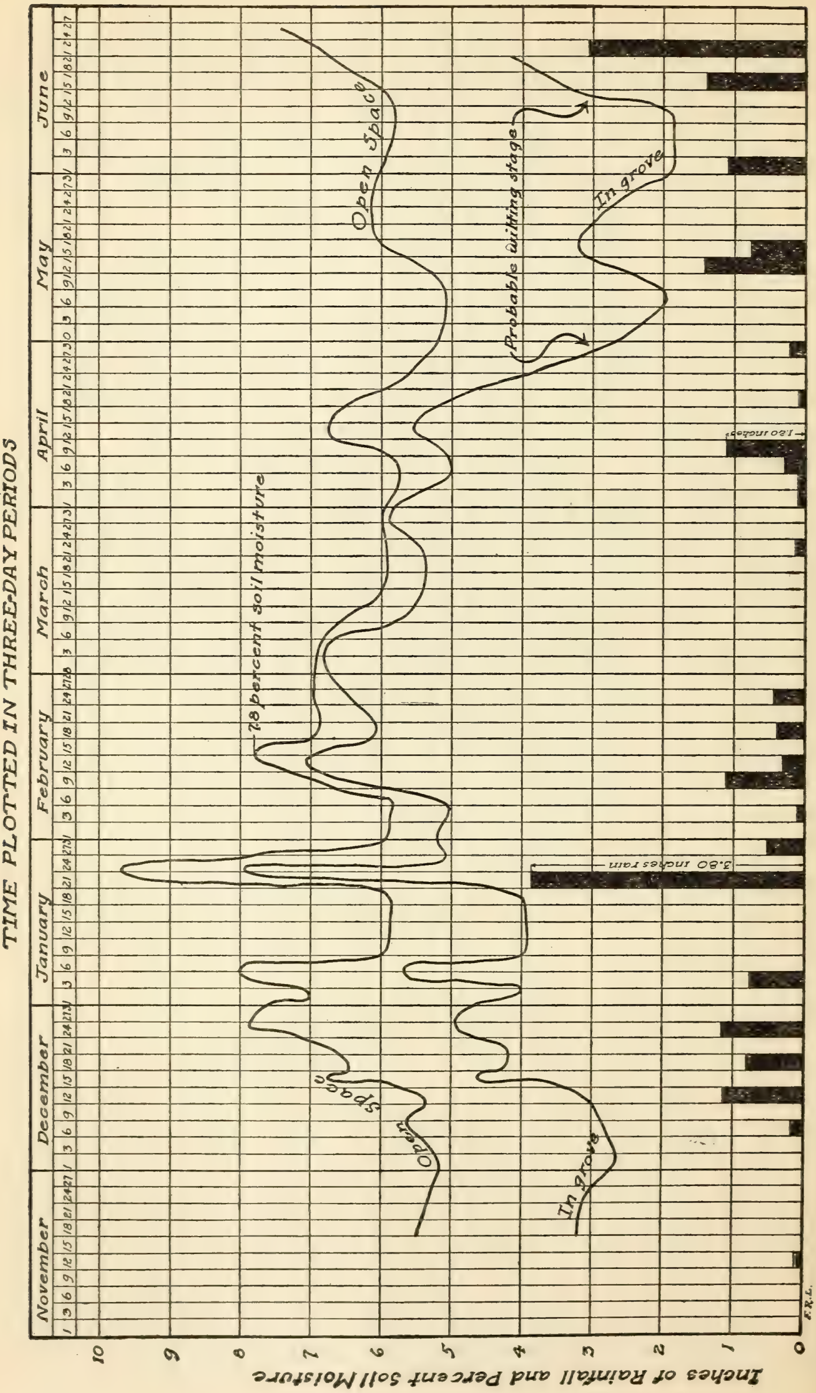

FIG. 5.—Curves showing effect of rainfall on soil moisture in sandy soil at Orlando, Fla., Nov. 15, to June 15, 1913–14.

chart, the soil in the grove was in this condition for the period from May 1 to June 9, with the exception of five days from May 12 to 16.

Other factors affecting the soil moisture which are not shown graphically are temperature and wind. February and March were cold and the evaporation was small, but April, May, and June were excessively hot. Many tests in the West show that the evaporation from an open, well-cultivated space is very small. With reference to the upper curve, it may, therefore, be assumed that the difference between the two curves shows approximately the effect of the groves upon evaporation, although the temperature in a grove is somewhat less than that in the open. However, the samples were taken as far away from the influence of shade as was possible while still well within the root area, and the trees were trimmed high, which permitted a good air current throughout.

This chart is especially valuable when used in connection with the rainfall charts (figs. 1–4). Taken together they give a clear idea as to soil-moisture conditions for the past 22 years, and from them it is possible to arrive at a fair average which should apply to the future as well as to the past. Space will not permit a thorough study of these problems, but from the charts it may be seen that there have been many periods in the past when the moisture content of the average orange grove has been below the 3 or 4 per cent which seems to be necessary for growth. It also may be seen that small amounts of rainfall in the warm spring months of April, May, and June are not of great importance, since the moisture soon disappears.

Figure 6 shows the effect of cultivation in a citrus grove. These tests were made in representative groves, and the curves show the average of a number of tests made at Maitland, Orlando, and Drennen Station, 4 miles south of Orlando. These borings were made at times of drought, most of the tests being made in May and June, 1914, at a time when the soil was very dry, as is shown in figure 5. The cultivated portions were kept in good condition throughout the season, a good dust mulch being preserved. The uncultivated portions were not disturbed at any time through the summer or winter. The soil, in some cases, was well packed, and in all cases it was covered with a heavy growth of grass and weeds, dead at the time the samples were taken. It would have been possible to keep the weeds and grass down, but this would not have represented true conditions, as grass and weeds grow in abundance where groves are not cultivated. The spaces designated in figure 5 as "open" were outside the radius of any tree roots. The curves for the grove show moisture content for full-grown orange trees. Soils, in all cases, were of the high-pine class.

The results shown by the curves need little comment. It is apparent that cultivation in the open spaces has had a marked effect

upon the soil moisture. The top curve shows good moisture content under the dust mulch, which is seen to be about 5 inches in depth, while the open, uncultivated space is seen to be very dry for the first 2 feet in depth. The curves for the cultivated groves show no such marked differences, although there is nearly 1 per cent more

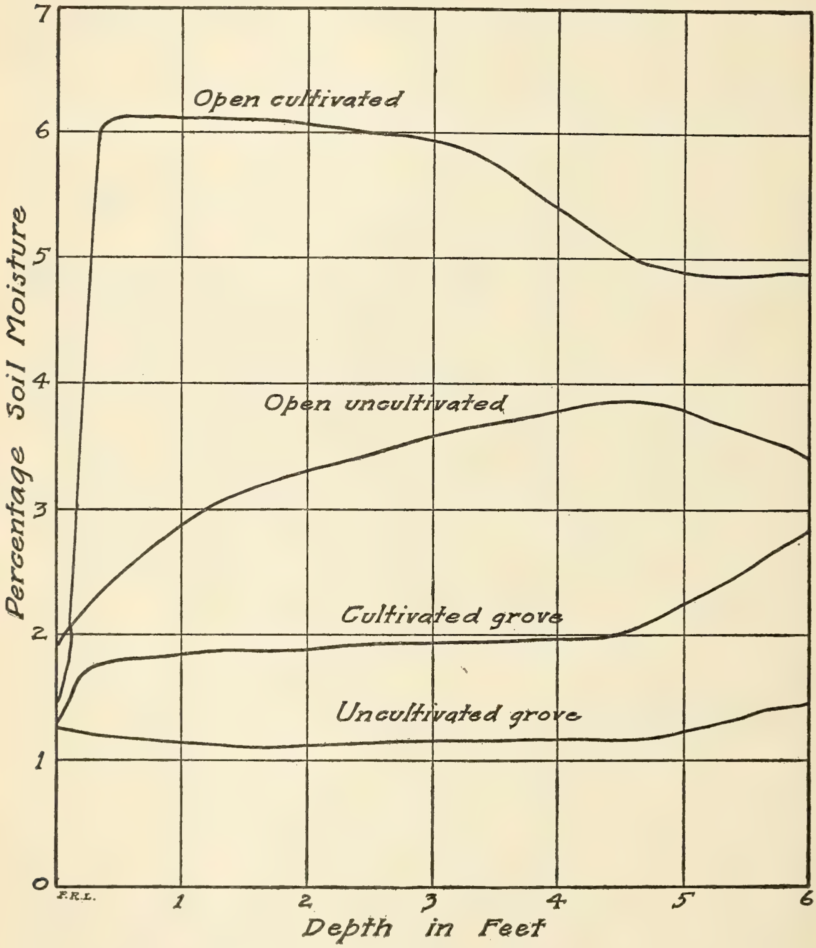

FIG. 6.—Curves showing effect of cultivation on soil moisture in citrus grove and open space at Orlando, Fla.

moisture in the cultivated grove; yet both curves are below the 2 per cent mark, which would show that both tracts were about as dry as could be. It is probable that the moisture represented by these two curves would appear to the eye to be about the same, the soil in both being dry enough to run freely between the fingers. The reader should be cautious, however, in drawing conclusions from these results. It can not be assumed, because there is so little differ-

ence in moisture content between the cultivated and noncultivated grove, that cultivation has done little good, as it is quite probable that the trees within the cultivated space have had the benefit of the moisture conserved by cultivation, which was lost through grass roots or evaporation in the uncultivated grove. Observation of the effects of cultivation shows that it will prevent wilt for some time after uncultivated groves are showing distress both in loss of fruit and by curling leaves. On the other hand, the moisture curves show conclusively that both cultivated and noncultivated groves have depleted their available moisture supply from the soil, which evidently can be supplied only by rain or irrigation. A great number of tests have proved this point beyond dispute, yet there are many growers in Florida who advocate that cultivation will take the place of irrigation. Scientific tests show that this can not be true in case of protracted drought, although it may be true for short periods of dry weather. In any case, it appears that it would pay to cultivate the groves during the dry weather if all possible moisture is to be conserved.

OTHER FACTORS DETERMINING THE NEED OF IRRIGATION.

The two factors treated above, rainfall and soil, doubtless are of primary importance in determining the need of irrigation in the State, yet there are a number of other factors that enter into the matter. Shallow-rooted crops, such as truck or small fruits, will suffer from drought much sooner than deep-rooted crops, such as orchards. The difference in the cropping also calls for a different type of irrigation system, as it is evident that the shallow-rooted crops, upon light soil subject to rapid drying, demand a system that will apply water rapidly and more often than is necessary for groves. The difference would be much more evident were it not for the fact that most of the vegetable crops are grown on low grounds which are not so subject to harm in dry weather.

The average field crops of Florida, as a rule, are not irrigated. There are two reasons for this: first, that most of the field crops either are grown in the northern counties where the rainfall is more evenly distributed, or in the southern counties after the truck crops are off, which usually is well toward the rainy season; and, second, that most of the field crops stand considerable drought and at the same time do not require such intensive cultivation as the truck crops or citrus fruits. The profits per acre usually are small compared with truck crops or citrus groves, and under ordinary conditions will not warrant an outlay for irrigation purposes.

Irrigation is used in some cases to prevent frost from injuring plants; in some citrus groves to combat insect pests. These problems will be treated later.

WATER SUPPLY AVAILABLE FOR IRRIGATION.

Practically every part of the State is well supplied with water for irrigation purposes, in the form of lakes, streams, or wells. The rivers are little used as an irrigation supply, either by means of diversion ditches or through the use of pumping plants, but the lakes and wells are used extensively both for irrigation purposes and for domestic supply.

The lakes are a constant surprise and delight to the new arrival, and are scattered from one end of the State to the other, varying from the size of a small pond to the huge Lake Okeechobee. The lands bordering many of the lakes offer promising sites for orange or grapefruit groves, since the lakes not only afford a water supply for irrigation but are a material aid in keeping up the temperature in times of cold waves. It would be difficult to approximate the number of groves that border lakes in the State, but a large percentage of the groves in Lake, Orange, and Polk Counties are so situated. The elevation of the groves above the surface of the lakes varies considerably in different sections, but there are few irrigation plants which elevate water more than 100 feet, while a fair average of them probably would show less than half this lift.

Where no lakes are available water usually is obtained from wells without much difficulty. The area in which flowing wells have been sunk is very extensive and includes much of the land lying below the 50-foot contour. The State geologist has prepared a map showing the artesian belt, and this map should be consulted if a newcomer is considering irrigation from flowing wells. In general, the area follows the east coast of Florida from Jacksonville to the Everglades, covers all the Everglades, then follows the west coast to a point a few miles above Tampa. This border varies in width, but as a rule does not extend many miles inland. Other areas yielding artesian flow follow in narrow strips along the St. Johns and the Kissimee Rivers, while there is another artesian belt on the mainland, bordering the Gulf from the Appalachicola River to the extreme western border of the State.

The depths of the flowing wells vary greatly throughout the State. Many of the wells around Jacksonville are more than 500 feet in depth, while near Hastings the wells are shallow, frequently being only about 125 feet deep. The wells in the Sanford district are shallow, often being less than 100 feet. The depth of those in the southern part of the State is very great, some wells near Palm Beach having been sunk 1,000 feet before a flow was obtained. The wells on the west coast, which furnish water by natural flow, also are of varying depths. The flowing wells in the Fort Myers district vary in depth from 400 to 800 feet, while a series of flowing wells in the

Manatee district probably averages 500 feet. Some of the wells in the Fort Myers and Manatee districts have a very heavy flow, registering as much as 20 pounds pressure when capped. One 6-inch well near Palatka, now used for irrigation, flows more than 1,000 gallons per minute at the well, and will force water to the second story of the house, which stands on an elevation some 10 or 15 feet above the well.

As the elevation of the ground surface increases the flowing artesian wells disappear. Much of the central portion of the State is in this higher area. The wells in the non-flowing artesian belt usually appear to be inexhaustible from a pumping standpoint. Many of the bored wells above the flowing artesian belt are used as drainage wells. These will take great quantities of water without materially affecting their own water levels. This fact is explained by geologists as due to the porous nature of the water-bearing limestone strata underlying the entire State.

Much water for irrigation is derived from driven wells, which usually draw on the surface supply. There are not many open dug wells, as the sandy character of the soil makes an open well difficult to manage. A few open wells in the Miami section, however, are dug in the limestone formation, and these supply water to a number of irrigation plants, some yielding large amounts of water.

DESCRIPTION OF IRRIGATION SYSTEMS IN USE IN FLORIDA.

The important types of irrigation practiced in Florida are: (1) subirrigation, (2) overhead spray, (3) grove irrigation, which includes many different systems, and (4) furrow irrigation, applicable both to truck crops and to citrus groves.

SYSTEMS FOR THE IRRIGATION OF TRUCK CROPS.

Sanford is located on Lake Monroe, in the central part of the peninsula, about 28 miles west of the Atlantic Ocean. The lake is formed by the widening out of St. Johns River, which is used for transportation purposes, and handles considerable freight between Sanford and Jacksonville. It will not accommodate the large ocean steamers, but will float good-sized river steamers. There also is direct railroad connection with the northern markets.

Practically all of the cultivated area in the Sanford district is devoted to the growing of winter vegetable crops for use in the northern markets. It also grows summer fodder crops for home use.

The soil, for the most part, is of the flatwoods type, although there is some low hammock in certain localities. Much of the land away from the river is practically level, although the general trend of the grades is toward the river. A considerable area adjacent to the river, however, has heavy grades, some of the lands falling several feet to

the hundred. The grades are uniform in the latter case, the contours running about parallel to the river's edge.

The surface soils of this flatwoods type generally are light and sandy, the percentage of sand increasing with the depth until the subsoil is reached. The upper 6 or 8 inches often is rich in organic matter and dark in color, but a large percentage of the soil between the first foot and the subsoil appears to be mostly sand of a whitish or yellowish tinge. The small areas of muck or hammock lands have deeper surface soils and more organic matter throughout. The sandy soils offer very little resistance to the rapid percolation of water in times of heavy rain.

Throughout the Sanford area there is a practically impervious subsoil underlying the surface at depths varying from 1 foot to 5 feet. This impervious substratum is sometimes composed of a clay, but usually is of a sort of sandstone which appears to be cemented together with a yellowish material apparently composed of organic materials containing considerable iron, and is very hard and nearly impervious. (See Pl. I, fig. 1.)

The water supply for irrigation use is obtained entirely from flowing wells which vary in depth from 65 to 200 feet, the shallower wells being located close to the river. It is reported that there are at least 1,000 flowing wells in this district, most of them being used wholly or partly for irrigation purposes, although a number may water private garden patches only. The cost of the wells varies with the size and depth. There are few wells in use, however, over 4 inches in diameter, while practically every farmer adopts the 2-inch size, which costs about $1 per foot complete. One well will irrigate 2 to 5 acres, depending upon the character of the soil and the flow of the well. A good 2-inch well will flow 30 to 100 gallons per minute, the better flow usually being on the lower elevations. It is a common practice for the farmer to have a number of 2-inch wells scattered over his farm rather than to attempt to get larger wells with greater capacity. Many farmers having 15 to 20 acres under cultivation will have four to seven wells, while others will make one well water 5 to 10 acres. The advantage of more wells is considerable, as rapid irrigation is especially desirable at the time of setting plants and depends upon the amount of water available.

SUBIRRIGATION AS PRACTICED AT SANFORD.

The application of water is accomplished by the so-called subirrigation method. Briefly stated, this operation consists of running water through underground tile laid with open joints so that the water escapes at the joints and percolates through the ground, thus watering the plants in the course of time. In order to water the entire ground surface, the tiles are placed in parallel rows as close

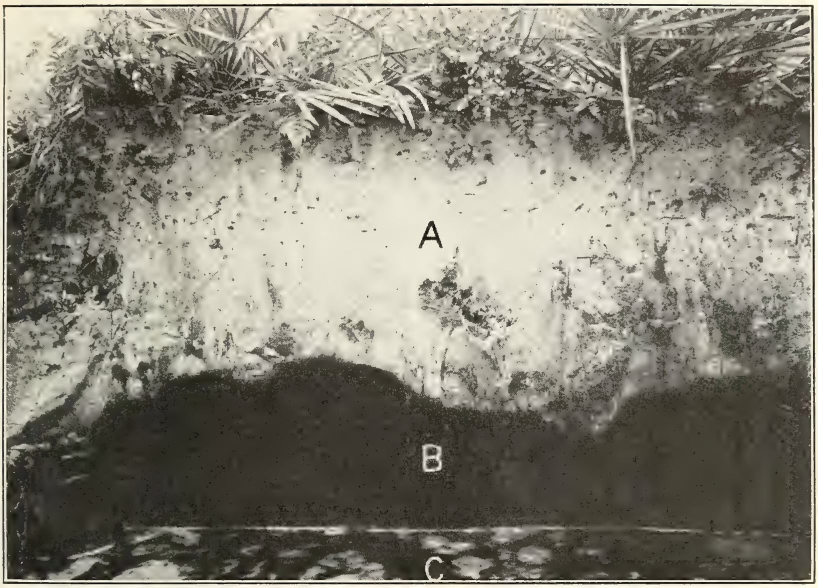

FIG. 1.—CROSS SECTION OF SOIL FORMATION IN SUBIRRIGATED SECTION, SANFORD, FLA.: A, LIGHT TOPSOIL; B, HARDPAN; C, WATER.

FIG. 2.—WATER-TIGHT MAIN AND STOP-BOX CONNECTION TO SUBIRRIGATION LATERALS, SANFORD, FLA.

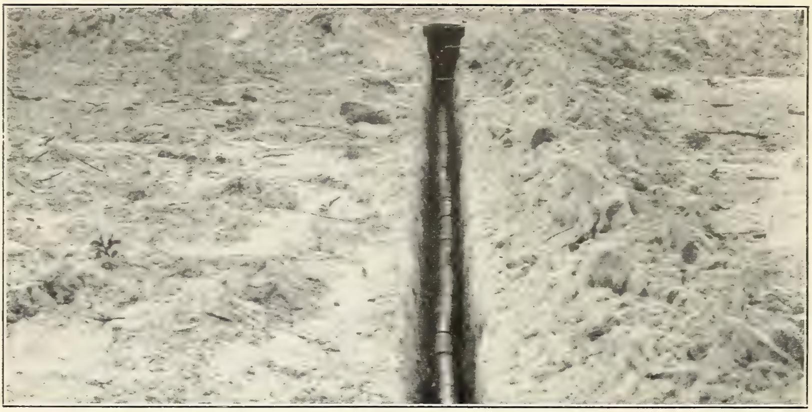

FIG. 1.—SUBIRRIGATION LATERAL TILE LAID IN TRENCH BEFORE JOINTS ARE COVERED.

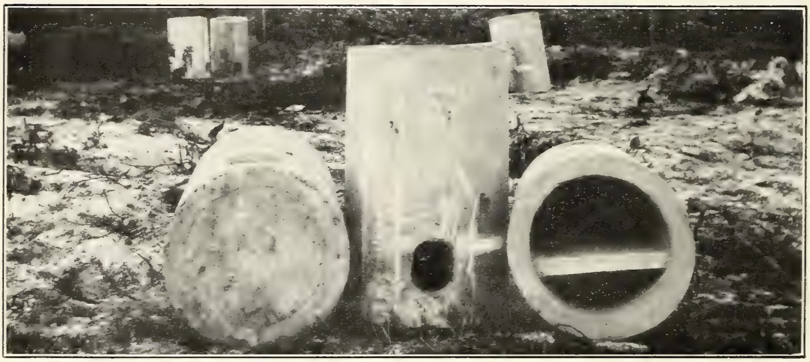

FIG. 2.—SUBIRRIGATION STOP POCKETS, SANFORD, FLA.

FIG. 3.—WATER SUPPLY AND TOOLS USED FOR SUBIRRIGATION, SANFORD, FLA.

together as experiment has shown to be necessary. In the Sanford district it has been found that irrigation is accomplished to best advantage when the tiles are placed 18 to 20 feet apart, although wider spacing is used in some cases. If the tiling is placed farther apart the irrigation will be uneven or will take too long. If the tiling is closer, the irrigation will be satisfactory, but the cost will be excessive.

The actual construction of a tile irrigation system requires considerable care and should be left to experienced hands. The following description of construction is taken from a report made to the Office of Public Roads and Rural Engineering by Milo B. Williams, irrigation engineer, who has had considerable experience in the construction of tile systems at Sanford:

The tile system consists of a water-tight main pipe feeding a series of open-jointed parallel laterals placed 16 to 18 inches below the surface. The mains are located on the highest side or on the ridges throughout the field, so that the laterals slope away from the mains at the proper depth. The mains are of 4 to 5 inch vitrified terra-cotta pipe, which is obtained in 2½-foot lengths, with a bell end. The joints are made water-tight with cement. A stop box is placed at the intersection of each lateral with the main. (Pl. I, fig. 2.) Holes are cut in the side of the pipe and a short length of 2-inch steel pipe is cemented into place to form a connection between the main and the head stop box, the laterals leading out from the stop box. This metal pipe also forms a neck into which wooden plugs may be inserted to control the flow of water. Where the main feeds two laterals leading in opposite directions from the same point the stop box is placed in the main line, with the laterals leading out from opposite sides of the box.

The laterals are built of 3-inch clay draintile (Pl. II, fig. 1), which is obtained in 12-inch lengths. The pipe is laid with open joints by placing the short lengths end to end. A shovelful of sawdust or cinders is placed over each joint to prevent the fine sand from working into the line and stopping the pipe. The grades for the lateral trenches vary from a 1-inch to a 3-inch fall per 100 feet. These grades generally are obtained by turning the water into the trenches before the tile is laid, so that the digger can remove all irregularities from the bottom of the trench. The ordinary expense of the Sanford system, however, would appear to justify a more careful method of establishing and maintaining the grades. At the time the system is laid out it would be well to establish the grades of the laterals by means of a level in the hands of a competent surveyor, and they should be maintained throughout construction. Laterals are spaced 18 to 24 feet apart, but the shorter distance has proved the more satisfactory.

Stop pockets are placed in the lateral lines at intervals of 100 to 400 feet for the purpose of checking the water in the laterals and thus securing a small pressure in the lines above the pockets. When pockets are used for this purpose a weir division wall is inserted near the inlet side containing two metal-lined openings (Pl. II, fig. 2), one a 3-inch hole on a level with the tiles entering and leaving the box and the other a 1-inch hole about 6 inches higher. When the water is not to be held in the pipe line above a box the lower hole is left open, so that the water can pass down the line freely. When the water is to be held up the lower hole may be plugged, raising the water to the upper hole, or both may be plugged, causing the water to rise until it flows over the top of the weir wall into the next section of the lateral. The weir wall is placed

nearer the inlet side of the box, making the chamber on the outlet side large enough to admit the hand easily to operate the plugs. For this purpose cypress plugs are often used. One of these consists of a large hollow plug fitted to the opening and a smaller solid plug which fits the hole in the larger plug. By this arrangement different sized streams can be obtained. The plugs often become water-soaked, making it difficult to remove them. Sliding galvanized-iron gates would be preferable.

The tools used in excavating and installing the tile are shown in figure 3 of Plate II. The mattock and ax are used for cutting the roots in the newly cleared land. The wide irrigation shovel is used for removing the topsoil and the curved adjustable shovel for cleaning out and forming the bottoms of the trenches.

The cost of the Sanford tile system ranges from $100 to $125 per acre, not including the water supply or drainage outlet from the field.

In the operation of the Sanford system water is turned into the main feed pipes and divided among a number of laterals by operating the intake plugs. The plugs in each pocket are adjusted so that the water will be backed up in certain sections and held there until the moisture meets between the tile lines. The water issues from the tile joints into the porous sandy subsoil and follows along on top of the impervious substratum until the surface-soil area is underlain with a sheet of water. If irrigation continues after this state has been reached the water will soon show on the surface.

Irrigation is begun when the first winter crops are planted in the fall. The ground is completely saturated to the surface to settle the young plants into place and give them a start. The common practice is to irrigate every 10 days to 2 weeks during the growth of the crop, depending upon the rains which occasionally occur during the winter season. Celery is irrigated 24 hours before cutting. This is thought to swell the plants and make them brighter and heavier.

The length of time required to saturate the Sanford soils varies greatly on the different farms. Some farmers use a large head from a number of wells, forcing the water into both ends of level laterals, thus causing saturation within a few hours. Others use smaller amounts of water and take 12 to 48 hours to irrigate. The amount of moisture contained in the soil prior to irrigation and the depth to hardpan determine materially the length of time necessary for saturation. It also takes longer to subirrigate a field on which a cover crop has been turned. Likewise, a soil finely pulverized is slower to irrigate than one that has not been cultivated.

Overirrigation is a common practice, and probably is more expensive than is commonly realized. On opening the tile lines to drain off the excess water large quantities of the fertilizing constituents applied in commercial fertilizers are carried away. This has taught the farmers in this section the need of applying fertilizers immediately following a heavy rain.

There are special cases about Sanford deserving of mention which have not been touched upon in the above discussion. Systems for the subirrigation of the fields adjacent to the river which have heavy grades should be laid out somewhat differently from those described above. If the mains were laid on the high side of the field and the laterals allowed to run down the slope having a grade of several feet per hundred, the water would not have sufficient opportunity to perform its task of irrigating the ground between the lines. In such a

situation the main line should run down the steep slope while the lateral should lead off perpendicularly or nearly so, following approximately the contours and having a very slight grade, as in the case of the level grounds.

Instead of a main line of terra-cotta pipe some farmers use an open trough or flume, letting water into the laterals by removing wooden plugs from the side of the flume and damming the water in the flume by check gates. When this method is used water does not percolate from both sides of the tile lines but runs one way only, or down the grade from one lateral to the other. This method, while used in other parts of Florida as well as at Sanford, is not so satisfactory in very dry weather as is the subirrigation of the level lands, some of the farmers having great difficulty in getting the water to the surface.

Another special method used to some extent in Sanford is irrigation without the use of a head main feed line. In this case the lateral tiles are laid perfectly level and are fed from an open ditch which also serves as the waste or drainage ditch in times of excessive rains. This method is somewhat of a makeshift, but works very well, and can be used for a while in this form when the farmer can not afford a heavier outlay. Sometimes the farmer will use this method and lay the tiling double distance, filling in the additional lines after he has grown a crop. The double spacing does not work so well for irrigation but will answer as a temporary expedient and at the same time drain the land, which in many cases probably is of more importance than the irrigation.

Concrete tile was used almost exclusively for laterals in the early development of Sanford subirrigation. Recently, however, concrete tile has been mostly replaced by burned clay tile, as the concrete broke down after having been in the ground a few years. The disintegration of the tile probably was due to the use of materials unadapted to the making of a good concrete and to improper methods of manufacturing and curing the product. Cheapness was sought at the expense of quality, and a very porous tile was produced which gave great opportunity for soil acids to attack the structure.

The most necessary condition for successful subirrigation is a porous surface soil overlying an impervious substratum, which is the formation found in the Sanford section, as shown by Plate I, figure 1. The topsoil is a porous, light-colored sand, while the subsoil is a dark-colored hardpan which holds the water until it has spread laterally through the sandy topsoil. If subirrigation of high pine land with a clay subsoil 8 to 10 feet below the surface is attempted, the chances are that water could be run in the tile a month without any appreciable effect on the surface soil. Several attempts have been made

to subirrigate lands of such type near Orlando, but in every case complete failure has followed. There have been also several attempts to subirrigate the heavy clay loams of Alabama, but with most disheartening results. The causes of failure are obvious in every case when the nature of subirrigation is considered. In the attempts made near Orlando the water was lost in the depths below the surface soil and would have had to fill up all the soil above the clay substratum before surface irrigation could take place. In the Alabama installations the clay surface soils were water-logged for a distance of a foot or two on either side of the tile, the soil beyond being perfectly dry.

In the Sanford district, however, the distribution of the water is not impeded by heavy soils. There the action of the water during subirrigation has been studied carefully with the aid of a soil-sampling apparatus. These tests show that the irrigation of the surface soils is not due so much to the action of capillarity as to the simple process of filling up the soils with water. Tests taken at the time of irrigation show that the soil reaches the saturation point 6 inches under the ground surface before the surface soils are irrigated sufficiently. It also is common to find free water standing in the soils at 1-foot depths when the plants are in need of irrigation. These tests, along with many others, show conclusively the nature of subirrigation.

It is evident that this system of irrigation requires large quantities of water, and consequently subirrigation under soil conditions similar to those at Sanford is not an economical method where the water has to be pumped. Nevertheless, it is common for the uninitiated to regard this method with favor on account of its supposed saving of water. The large quantity of water needed is no particular drawback to the Sanford farmer because the nature of the water supply assures him an unlimited quantity at no operating cost.

A comparatively even ground surface, or a uniform slope, is required for successful subirrigation. If the ground is uneven the low places will become flooded while the high knolls will not be irrigated sufficiently.

Another factor in the successful operation of a subirrigation system is the correct kind of cropping. It has been stated that the Sanford district depends almost entirely on garden products. These crops invariably are shallow-rooted, most of the plant roots feeding within 6 inches of the surface. These, being annual plants, do not have an extensive root system. It has been demonstrated in the West that the subirrigation of trees is a failure on account of the stopping up of the tile by tree roots. This is especially true if the soil is rich in plant food to the depth of the tiling. On the other hand, there are records of successful subirrigation of citrus groves through tile sys-

tems in Florida, but in such cases it is possible that the water plane stood above the tiling for long periods, thus preventing the entrance of tree roots, as the roots of most cultivated trees will not penetrate below the level of the usual water plane.

There are several groves near Terra Ceia that are subirrigated and at least one grove near Palatka. At the present time these systems are working well, and are especially valuable from a drainage standpoint. As these installations are new it can not be determined how long they will withstand clogging by the tree roots. The subsoil surrounding the tile may be of such character as to keep roots away from the tile or the ground water may be high enough to discourage deep rooting. Still there is considerable danger of clogging if the ground water should be lowered by protracted drought or by artificial drainage on a large scale.

A common rotation of crops in the Sanford trucking district is as follows: first, lettuce is planted about September 1 and harvested about the middle of October. This is followed by celery, which should be harvested by February. Cucumbers may follow immediately and should be off the ground by the first week in May. Corn then can be planted and harvested in August. There still remains enough time to grow a crop of native hay before the time to plant lettuce again.

Many of the farmers follow an entirely different schedule, although most of them plant celery. Some plant celery in October and get two crops, the last crop being harvested in July. Others plant beans, cabbage, cauliflower, and various other vegetable crops, while still others plant a considerable acreage of potatoes. The winter truck crops are shipped to the northern markets, while the corn and hay crops usually are consumed at home.

It has been stated that the cost of tiling averages $100 to $125 per acre. This would be a heavy outlay for many crops, but when the total cost of equipping land and the annual expense of growing a celery crop is considered, the cost of irrigation does not seem exorbitant since the cost of equipment, outside of irrigation, is about $450 per acre.

It should be emphasized that the Sanford subirrigation method serves also for drainage—entirely, in fact, for some crops. This is true especially for the summer cropping during the rainy season and frequently during heavy rains in the winter season. There are some disadvantages in having subirrigation and drainage systems combined, one being the large loss resulting from the draining away of expensive fertilizers; and another, the need of saturating the soil in order to get enough moisture at the surface. Even if other methods of irrigation were used, however, it would be necessary to have drainage systems installed to take care of excess water, and when it

is considered that the maintenance and operation are at an absolute minimum, it may be seen that the Sanford system of irrigation is satisfactory where conditions discussed above are favorable.

OTHER FORMS OF SUBIRRIGATION IN FLORIDA.

Several other localities use the tile systems for irrigation and drainage. Several hundred acres in the Manatee trucking sections are irrigated by this method, as are about 200 acres along the shores of Lake Apopka in Orange County.

Most of the tiling in these localities is similar to the systems described for Sanford, although there are exceptions. Some of the Manatee farmers use boards nailed in V-form instead of tiling. This is done in soft, springy lands where it is hard to keep tiling in alignment. It is doubtful if boards should be used even in such soft ground, and a common practice among drainage men is to lay ordinary clay tiling upon a single board placed in the bottom of the trench where the soil conditions are not favorable for tiling alone. The boards will rot out in about 10 years, while good tiling will last much longer, although it needs to be cleaned out occasionally.

The contour methods of subirrigation are practiced mostly along Lake Apopka, where the grades are too steep for the ordinary methods. Much of the trucking section here is in a narrow strip along the lake and some of the grades are quite steep, the land having a fall of several feet per hundred. Flowing wells are obtained at the lower levels on most of the farms, but they will not force the water to the top of the main, consequently it is common to install a small engine and low-pressure pump to act as a booster.

There are also isolated cases where there is no impervious substratum of hardpan to permit successful subirrigation. Such farms have a water plane standing within 3 or 4 feet of the ground surface and this saturated soil seems to act as a hardpan, preventing the loss of irrigation water. These instances prove conclusively, in the writer's opinion, that capillary attraction does not play an all-important part in the subirrigation of the sandy soils of Florida, for were this the case it would not be necessary to irrigate garden products when the soil 3 feet below the surface is saturated.

OPEN-DITCH SUBIRRIGATION AT HASTINGS.

Another method of subirrigation is that practiced in the potato district near Hastings. This is the largest irrigated area in the State, consisting of about 10,000 acres, of which 7,000 acres are in St. Johns County and 3,000 in Putnam County, all within the so-called Hastings district. Probably two-thirds of the potato crop in this territory is irrigated, practically all by the open-ditch method.

This section is very similar to the Sanford trucking district, both as to its soil conditions and its water supply. The ground surface in general is very level and the soil is of the flatwoods variety, interspersed with patches of low hammock lands. The highest elevation is about 17 feet above sea level, the average being about 10 feet. The potato lands are underlain with an impervious stratum or hardpan at depths varying from 20 inches to 5 feet.

The water supply is from flowing artesian wells (Pl. III, fig. 1), the average depth of which is about 200 feet. Some of the wells give a good flow at 110 feet, while others are nearly 400 feet deep. Most of them are 4 inches in diameter; the diameter of the average Sanford well is 2 inches. A good 4-inch well will supply about 300 gallons per minute. The cost of the wells increases with the depth, the average cost being about \$200 to \$300, or \$1.50 to \$2 per foot, complete.

In most cases water is applied to the crops through open field ditches placed in parallel rows 30 to 40 feet apart. (Pl. III, fig. 2.) These ditches are fed by a main ditch which runs at right angles to them. The dimensions of this vary somewhat, but it usually is about 2 feet on the bottom, 1½ to 2 feet deep, and 7 to 10 feet wide on the top. The slope often is gradual enough to accommodate a row of potatoes along the banks. The head ditch in the average farm is a partnership affair running along the road, and is used as a general drainage ditch when necessary.

The water runs from flowing wells into the main head ditch, from which it is led into the field ditch. The water is controlled from the main to the laterals by simple wooden gates, or, in some cases, by temporary dirt embankments thrown up with a shovel. As at Sanford, the grades are very slight and the head of water often is relied upon to force a flow. The process of irrigation consists of filling the field ditches and keeping them so until the soil between them has become subirrigated. The action is essentially the same as that at Sanford, the open ditches merely taking the place of the underground tile.

The amount of water needed per irrigation by this system and the time required depend upon the amount of moisture in the soil. Generally a 4-inch well flowing 300 gallons per minute will irrigate 40 acres. In times of protracted drought the well is run continuously, one well taking care of 40 acres. The need for one 4-inch well on every 40-acre piece is accepted generally. If the flow is 300 gallons per minute, this means a duty of water of 7½ gallons per minute per acre. This is not far from the amount allowed for some of the irrigation systems of the West. The time of irrigation depends upon the rainfall. No irrigation is needed in some years, while in others water is required during a large part of the growing season.

The cost per acre of a system for the irrigation of potatoes is exceedingly low. This is worthy of notice, as the average cost of irrigation in Florida for many of the systems is very high. An allowance of $300 as the cost of a well to water 40 acres would mean an expenditure of only $7.50 per acre. The field ditches are cheaply constructed, and part of their cost may be charged properly to drainage. The cost of operation and maintenance is practically nothing for an average-sized field, as the farmer can care for the irrigation while engaged in other duties.

The most serious disadvantage of this system is the waste of land due to the open ditches in the field. These ditches, which are a continual nuisance in cultivating the field, also harbor weeds. It is doubtful, however, if it would be a profitable investment to tile the lands and do away with the ditches, although some tiling is being installed. First cost is an important item to most farmers, and the waste of a little land is not a very serious matter in this section where land is cheap and uncleared land abundant.

OVERHEAD-SPRAY SYSTEMS.

Overhead pipes, bearing nozzles or upright pipe with revolving heads, are used extensively in the State. It has been estimated that 3,000 acres are irrigated in Florida by some form of overhead spray.

The spray irrigation plants probably are more widely scattered over the State than those of any other type. There are plants in Gadsden County, in the northern section of the State, and others of all sizes and descriptions in nearly all the intervening counties down to the southern part of Dade County, on the southernmost tip of the peninsula.

Several localities are supplied with a considerable number of spray-irrigation systems, the largest area being in Polk County around Barstow and Fort Meade. There is also an important spray-irrigation center in Sumter County around Bushnell and Webster, and in Levy County around Williston. Several other sections likewise are represented, a considerable area being on the lower east coast around Miami. Some of these plants will be described in detail and an attempt made to present the important problems in each case.

The most common type of overhead-irrigation system is of comparatively recent invention. It will be called the overhead-pipe system in this bulletin. In this system water is distributed (Pl. IV, fig. 1) by forcing it under pressure through small brass nozzles, which are set 3 to 4 feet apart in carefully aligned elevated pipe. The pipe bearing the nozzles is laid 6 to 7 feet above the ground on posts set in straight lines about 15 to 20 feet apart. The overhead pipe is so constructed that it may be rolled in bearings by means of

FIG. 1.—FLOWING WELL AT HASTINGS, FLA., USED FOR SUBIRRIGATION.

FIG. 2.—SUBIRRIGATION FROM OPEN DITCH AT HASTINGS, FLA.

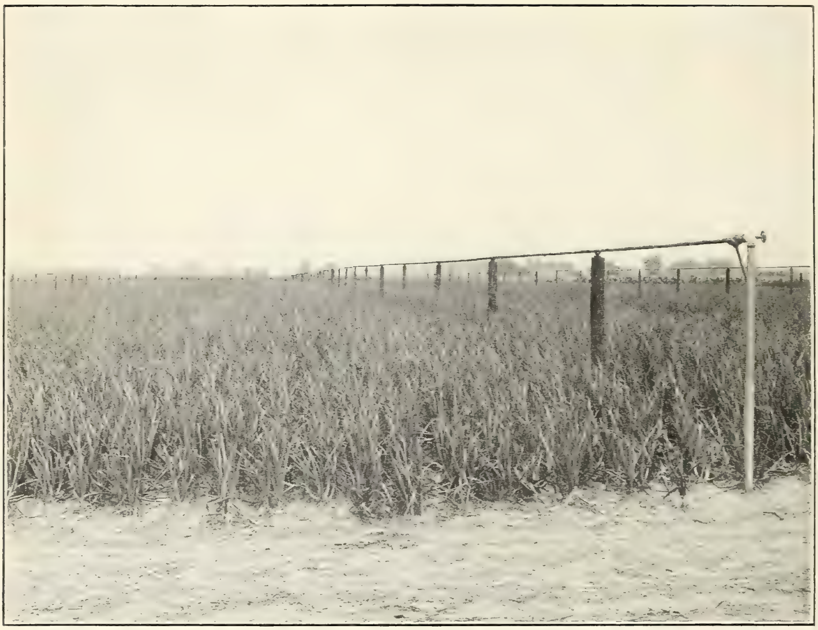

FIG. 1.—OVERHEAD-PIPE IRRIGATION SYSTEM, SHOWING PIPE LINES SUPPORTED ON POSTS.

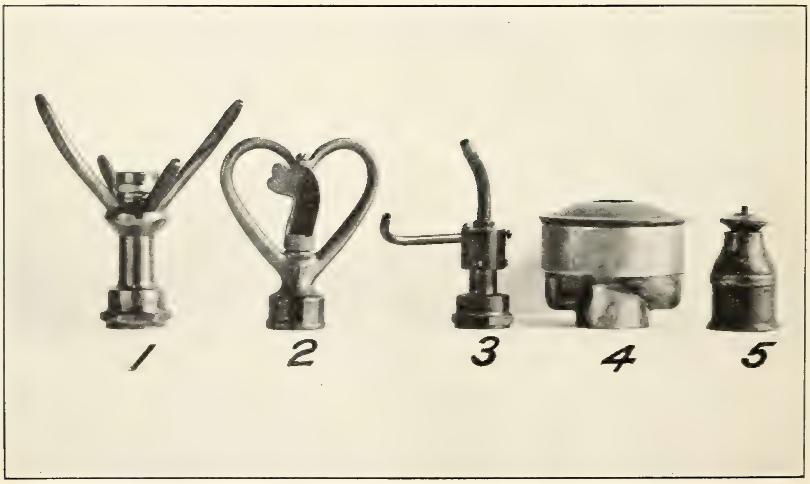

FIG. 2.—COMMON TYPES OF SPRAY NOZZLES USED FOR IRRIGATION IN FLORIDA.

a turning union. Thus when the pipe is turned to any one position every nozzle in it will assume the same angle with the horizontal. It is possible to turn, from one end, a pipe 700 feet long bearing 200 nozzles. The pipe lines usually are placed 50 feet apart, so that the nozzles in each line will throw water 25 feet on each side of the pipe. Each of these overhead-pipe lines is attached to the main supply pipe, the latter, in turn, being connected with a pumping outfit.

Several patented appliances are used in this system, two of the most important being the nozzles and the turning unions. The nozzles are small, ½ to ¼ inch in length, with an outside diameter seldom larger than a lead pencil. The aperture for letting out the water usually is about the size of an ordinary pin. Each nozzle contains an outside thread which enables it to be screwed into a drilled and threaded hole in the pipe. The water is forced through this miniature nozzle at a pressure of 30 to 40 pounds per square inch, throwing a stream of water 25 feet from the pipe if the angle of the nozzle with the horizontal is approximately 45 degrees. When several hundred feet of pipe bearing a number of nozzles are in use and each nozzle is throwing water 25 feet from the pipe a continuous strip of land will be watered. When it is desired to water another strip, the pipe is turned. It usually is necessary to turn the pipe through six or seven positions in order to water the 50-foot strip covered by one line. As a rule, this pipe is turned by hand, although there are several appliances on the market which turn the lines automatically.

The design of the pipe lines is an important item. The lateral pipe lines bearing the nozzles are of constant size for a given length. Tables have been prepared by dealers in irrigation supplies which give the sizes of pipe necessary for different lengths. In general, it is customary to begin at the lower end with ¾-inch pipe; run this for about 100 feet, then increase to 1-inch pipe, run this for another 100 to 150 feet, and so on until 2-inch pipe is reached.

TABLE 1.—*Sizes of pipe for outdoor nozzle lines.*

[Calculated on outdoor nozzles placed 4 feet apart. If the nozzles are closer together larger pipe must be used.]

Nozzle No.	Length of line.	¾-inch pipe.	1-inch pipe.	1¼-inch pipe.	1½-inch pipe.	2-inch pipe.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
No. 2 outdoor, 4 feet apart, or No. 1, 3 feet apart	150	115	35	....	....	......
	200	100	100	....	....	......
	250	90	100	60	....	......
	300	90	100	110	....	......
	400	80	100	120	100	......
	500	75	100	120	120	85
	600	75	100	120	120	185

The size of main needed depends on the number of laterals it is required to operate at once, or, in other words, the acreage that is to be watered at one time.

Table 2 gives sizes of mains needed for different quantities of water, according to the acreage to be watered. The data in this table are of a general nature and may be modified to suit the specific conditions. By following the sizes of the pipe as indicated below there will be ample capacity for the successful operation of the system under all conditions encountered.

TABLE 2.—*Size of pipe for main supply line.*

Discharge in gallons per minute.	Length of line in feet.							
	50	100	200	300	400	500	600	700
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
30	1½	2	2	2	2½	2½	2½	2½
75	2	2½	2½	2½	3	3	3	3
100	2½	2½	3	3	3	3½	3½	3½
150	2½	3	3	3½	3½	3½	4	4
200	3	3½	3½	4	4	4	4	4
300	3½	3½	4	4	4	4	5	5
400	4	4	4	5	5	5	5	6
500	4	5	5	5	6	6	6	6

The above system is in operation on about 150 acres within a few miles of Williston, in the north-central part of the State. The plants are mostly small, usually irrigating not more than 10 acres, one plant which irrigates 55 acres being an exception. The water supply for this plant is obtained from a bored well about 100 feet in depth, and is pumped from the well into the main by a steam duplex pump with rated capacity of 700 gallons per minute, operated by a 70-horsepower steam engine. The plant is designed to irrigate about 20 acres at one time, which requires a 7-inch main at the start. This is reduced to a 5-inch main at the end of the field, and might be reduced still more but for the fact that this pipe supplies water also to about 60 acres of surface-irrigated land. Much of the pipe is second-hand, and there is no record of its cost, but it is estimated that to replace it with new galvanized pipe would cost about $100 per acre for the field laterals and an additional $150 per acre for the pump, engine, and the main. This would mean a total cost of $250 per acre, or approximately $13,750 for the system, complete. The owner burns wood, which is plentiful in this section. He estimates that with wood he can operate his plant for 24 hours, the wood costing only $1.25 per cord. This is exceedingly low for operating expenses. The plant is run day and night continuously when it is in operation at all, owing to the difficulty of getting up steam every day; also because irrigation at night is found to have a number of advantages, such as smaller loss by evaporation and prevention of scald.

Cucumbers are the principal crop grown in the Williston section. There is much controversy concerning the effect of spray irrigation upon this crop, although all the systems were installed for the purpose of watering cucumbers. Some of the farmers owning irrigation plants are very much opposed to spraying cucumbers, claiming that the water applied on the leaves by the spray systems materially increases blight or rust. Many owners are willing to sell their systems at a great sacrifice. Others claim that blight is as troublesome where there are no irrigation plants. The consensus of opinion seems to be that care must be exercised in the application of water on account of this disease.

One advocate of spraying for the irrigation of cucumbers claims that he has paid for his plant easily by the added yields from irrigation within the last few years. He considers the spray system valuable not only because of its ability to supply water in dry times, but also for the purpose of preventing injury to the young plants by the blowing sand, from which more or less trouble is experienced during the spring.

Opinions differ concerning the use of the spray system as a protection from frost, some claiming that a medium frost will do no harm if irrigation is begun immediately before daylight and continues for some time after the sun is up, while others believe that no harm will come to the plant if the frost is washed off early in the morning. Many irrigators claim they have tried the overhead spray as a frost protector with absolutely no benefit. Whatever the fact, it does not seem to be a general practice to depend on the irrigation plant for frost protection in spite of considerable evidence in its favor. There is no doubt that spraying is of little use, however, in time of extraordinary cold weather or when the thermometer registers below the safety point for a considerable length of time.

Experience with steam pumping plants in this district indicates that, while economical in operation, they have some serious drawbacks, chief of which is the inability to irrigate immediately on account of the necessity to get up steam. This might be a serious objection in times of sudden high winds, which might cause much damage before the irrigation plant could be put into operation. The same might be true to a less degree in times of sudden drop in temperature. Gasoline engines can be started at once when in good running order. It should be stated in favor of the steam engine, however, that it is kept in order easily, while as much can not always be said of the gasoline engine.

The time and number of waterings necessary are dependent on the rainfall, except when frost or blowing sand must be combated. In any case, the time of irrigation is entirely dependent upon the weather conditions. Dry weather in the spring causes great loss

some years, and the disastrous droughts of 1907–1910 were the direct cause of the installation of most of the plants. Some farmers have not used their systems for irrigation for two or three years, but most of the growers found water of great benefit in the spring of 1914. In case of a protracted drought water may be turned on nearly every day and run only a few hours, or a good wetting may be given at intervals of a week to 10 days. The quantity of water applied is not difficult to estimate, most of the plants delivering 40 to 50 gallons per minute per acre, which is equivalent to about 0.1 inch of rainfall per hour. Thus, if a man operates his plant 8 to 10 hours he probably will apply about an inch of water.

It is a peculiar circumstance that the irrigators in this section should have adopted overhead methods so readily when most of the soil conditions are well fitted for surface methods. Some farmers believe that watering by surface methods will increase blight, but there seems to be little proof of this. At present about 75 acres are watered by the surface or furrow methods, apparently with excellent results. The method of distributing the water is crude and much labor might be saved by better methods.

The question of methods will be taken up under a discussion of furrow irrigation. There is no doubt that it is worth much study, for if results can be obtained by irrigation plants of low cost it is quite certain that many farmers who now hesitate to pay an average of $250 per acre for a plant would be willing to expend $50 per acre.

The trucking section in Sumter County is considerably larger than that in Levy County. The largest acreage of irrigated lands is around the town of Bushnell, about 50 miles south of Williston. Some irrigation is practiced near Center Hill and Webster, each within 11 or 12 miles of Bushnell. This district comprises 250 to 300 acres of irrigated crop, nearly half being located around Bushnell. Practically all of this tract is irrigated by the overhead-pipe system, but a few acres are irrigated by other spray systems and a few by surface methods. The soil conditions are not favorable here for surface irrigation under the ordinary methods of applying water, because of the flat ground surface and the sandy character of the soil.

The water supply is from wells, which average about 125 feet in depth, the water rising to within 50 feet of the surface. Most of the irrigated farms are small, few being over 10 acres in extent, while many contain only about 3 acres. For this reason gasoline engines are in favor, few steam plants being in use.

Cucumbers are the principal irrigated crop, as in the Williston section. There is a large acreage of beans and tomatoes near Webster and Center Hill, but irrigation of these crops is not a common practice, the farmers believing that the increase in yield due to irrigation will not warrant the outlay for installation.

Many of the cucumber growers use an ingenious device for protection against frost. When indications point to coming frost the young plants are covered with wooden troughs 10 to 14 feet long, made of two 1 by 9 inch or 1 by 10 inch boards nailed together in the form of a V. These troughs are removed the next day, and when not in use, are allowed to lie between the rows. About 10,000 feet of lumber is required to protect an acre of vines, costing about $120 to $160. This is in addition to the average cost of $250 for an irrigation plant, making an outlay of $400 per acre, exclusive of the cost of the well, the land, and the growing of the crop. The common use of troughs for protection against frost on the same lands that are irrigated by overhead systems indicates the unwillingness of the growers to rely on spray irrigation for protection against loss from cold weather.

Another section of interest where overhead irrigation is practiced is in the vicinity of Bartow and Fort Meade in Polk County, 60 miles south of the Sumter County trucking section. About 450 acres are irrigated in this district. The chief crops are lettuce, cabbage, tomatoes, and eggplant, their importance being about in the order named. A good summer crop is sweet potatoes, which often yields heavily.

The average size of these irrigated farms is somewhat larger than that of the northern counties, being about 20 to 25 acres. One overhead-spray system covers an area of 100 acres. On this farm the water is supplied to the mains from bored wells by three gasoline engines and three 2-stage centrifugal pumps.

The owner irrigates about once a week during dry weather, giving the ground a good watering at each irrigation. He starts his engine late in the afternoon, running them 8 to 10 hours. This irrigation is equivalent to approximately 1 inch of rainfall. He says that he would not attempt truck farming without such a system, which he finds valuable at the time of setting the young plants and again at the time of maturing them. He uses small pasteboard boxes for covering young tomato plants when cold weather is expected. Some farmers, before an expected frost, cover the small plants with soil, uncovering them the next morning. Thus, in this section also, overhead systems are not generally used for protection against frost. The small cardboard boxes are cheaper than the troughs used at Bushnell, and are not such an impediment to cultivation when not in use.

A detailed description of other examples of overhead-pipe systems would be of doubtful value on account of their similarity to those already described. Probably 1,500 acres under other overhead-pipe systems are distributed over the State, several hundred being scattered through Manatee and Hillsboro Counties, mostly in small

patches used for the cultivation of winter garden crops. A considerable acreage so irrigated is located in Lake and Orange Counties, the largest part of it being near the towns, such as Orlando and Leesburg. There are about 200 acres under the overhead-pipe system along the Florida East Coast Railroad, principally near Miami. Some tobacco was irrigated by this system in Gadsden County in the north, a small area at Brookville in Hernando County, and at Dade City, in Pasco County.

Several other sprinkling systems are attracting considerable attention. The method of distribution for all of these is practically the same, however. It consists in placing nozzles upon upright pipes and distributing the water in a circular area, the nozzle being the center of the circle. If a field is to be watered, a number of nozzles are placed over the field so that when all are in operation the whole area will be watered simultaneously.

A large variety of nozzles are used for the distribution of water from these upright pipes. Most of these are patented and bear the names of the inventors. Probably the first to be put into operation were those which have no revolving parts. (Pl. IV, fig. 2, Nos. 4 and 5.)

Another nozzle has been in use for several years. (Pl. IV, fig. 2, No. 2.) There are several variations of this nozzle. The distribution is effected by a revolving part which whirls very rapidly and throws the water in all directions. The water falls in large drops.

Other nozzles recently have become well known. (Pl. IV, fig. 2, Nos. 1 and 3.) These also distribute the water by means of revolving parts, but on a different principle from that of the ones described. The water is distributed through hollow, adjustable arms of small brass tubing, revolving about a central axis. The action of the nozzles is adjustable. Both the nozzles are operated by the force of escaping water; in the former the water strikes against the revolving part, and in the latter the force comes from the recoil of the water in a bent tube. Most of the well-known lawn sprinklers having long revolving arms are operated on the latter principle. The irrigation nozzles differ from the lawn sprinklers in that wider distribution is attempted, the size of the nozzle being kept as small as possible. All the nozzles described are small and may be covered easily by the hand. (See Pl. IV, fig. 2.)

Some attempts have been made to adjust pipe lines bearing nozzles so that a long length of pipe can either be revolved about a vertical axis or carried on wheels from one end of the field to the other. Both of these methods have been operated successfully at Bushnell, but their use is too recent to prove their lasting qualities.

The largest acreage irrigated by means of the stationary or revolving nozzles is on the east coast around Miami. Several hundred acres here are so irrigated. These types are also installed on 200

to 300 acres in the western part of the State, the largest acreage being in Polk and Hillsboro Counties.

Spray irrigation has been found to be of considerable value as a protection against frost in the southern part of the State. Some farmers claim they have saved their entire crop from frost injury by their spray systems.

The installation of a complete irrigation system covering several acres by means of these nozzles does not differ greatly from that of the overhead-pipe system, the pumping outfit and main line being similar in both. The lateral lines of the overhead-pipe system must be elevated above the ground surface, as every nozzle is turned on at once. The laterals of the other systems usually are placed underground, while the nozzles are elevated by means of upright pipes connected to the underground lines. In the overhead-pipe system the lateral lines are placed perpendicular to the main, the size of the pipe increasing toward the main as the length of the lateral line is increased. The circular nozzles are placed close enough together so that water from one will overlap the space watered by its neighbor. The parallel laterals also must be placed close enough together for the irrigated spaces to meet. It is evident that this distance will vary with the radius of distribution of the nozzle. The nozzles of alternate laterals usually are placed opposite, so that the circular areas covered by all the nozzles will fit into each other.

It is not necessary to go into details of the design of pump and engine, as it will be seen that if the capacity of each nozzle is known the problem differs in no way from that of the overhead-pipe systems. The stationary-nozzle types usually require considerably more water than the other system, and this means larger pipe lines if the same amount of land is to be irrigated at one time. Each lateral is fitted with a cut-off, as in the case of the overhead-pipe system, so that any amount of land required may be watered simultaneously, provided the main and the pumping outfit are of proper size and capacity. The pressure required is about the same for all the overhead systems.

Advocates of the whirling-nozzle type claim that their systems are automatic and need no turning by hand. The advocates of overhead-pipe systems claim that this difficulty can be overcome easily by installing an automatic turning machine, and that the turning of the lines by hand is very simple and requires little time away from other work. The small aperture in the overhead-pipe nozzle may cause trouble by becoming clogged with small pieces of sand or fiber. This does not happen usually with some rotation nozzles, but may stop others. Good screens or filters will stop this trouble to a large extent. The smaller nozzle may be cleaned with a pin and the rotating nozzles

started again with little trouble. The manufacturers of both types have sought devices that would prevent the clogging of the nozzles, and improvements are being made constantly for both. The larger amounts of water applied per minute is one of the main advantages claimed by the advocates of the whirling-nozzle type, the opinion being that more water is needed for the east-coast soils than is commonly supplied by the overhead-pipe system. This is denied by users of the latter system, who claim they get good results, and in any case could get more water by placing the nozzles closer together and using larger lateral pipe. Probably the main difference in the system is that the overhead-pipe system must have posts placed in the field, which are more or less of a nuisance, some trouble to keep up, and are often unsightly, especially in Florida, where it is common practice to use posts that are cut on the farm. The other systems present a much neater appearance, which is especially pleasing in the case of the irrigation of a flower garden or a private winter estate. For this reason, many of the large estates near Miami are watered by these systems on this account. The matter of appearance, however, is of little importance to most irrigators.

There is a great difference in cost, which often is of primary importance. Some of the systems covered by the old stationary nozzles. used for watering gardens, have cost more than $500 per acre. This high cost is due to the necessity of placing lateral lines close together. From $200 to $500 per acre probably would be an average cost for a complete system for a 5 to 10 acre truck patch. The average rotating-nozzle type will average $200 to $350 per acre installed, and the overhead-pipe system $175 to $275. Some of the stationary-nozzle systems are not liable to get out of order, and will accommodate almost any kind of dirty water. Other rotating-nozzle and overhead-pipe systems do not operate well unless the water is clear.

The distribution of water is better effected by the overhead-pipe system than by any other, being practically perfect if the lines are turned at the proper time. Distribution by the whirling nozzles depends considerably on the wind. If there is a good breeze the distribution will be even, but if the air is still there is unevenness in watering on account of the untouched spaces between adjacent circular watered spaces. The smaller nozzles of the overhead-pipe type apply water in fine drops, which is of considerable benefit in some localities, but it is doubtful if this makes any appreciable difference in the sandy soils of Florida.

The advantages of the overhead-spray systems are many, the chief ones being the ease of irrigation and the absolute lack of manual labor attached. The rapidity of applying the water and the evenness of distribution are of great importance, especially at the time of set-

ting young plants. This advantage is of more consequence in Florida than in the more northern States on account of the exceedingly sandy nature of most of the surface soils. The rapidity with which these soils dry out makes frequent irrigation necessary in dry weather, and this can be done easily with the overhead system without wasting water below the root area. It is necessary to fertilize most of the truck crops in Florida very often in order to assure rapid growth, but fertilizer is of little effect if the surface soil is dry. The overhead system dissolves this plant food and makes it effective in a short time. As has been pointed out already its value as a protection against frost has not been thoroughly demonstrated in all parts of the State but there are many overhead systems which are used successfully for frost protection, especially in the southern section. The use of spray systems for washing off dust and certain lice from plants is advocated by some, and the application of certain insecticides through the pipe lines has been suggested, but so far as the writer is aware this has not been attempted in Florida.

The disadvantage of this system lies primarily in its high cost of construction. An outlay of $200 to $500 per acre is heavy and means that the application of the water must bring in additional income above the cost of maintenance and yearly interest on the first outlay. The cost of operation is very light in most cases, averaging not more than $3 to $5 per acre per year for fuel. Labor cost of irrigation may be neglected for the small plant, and most of them are small. Depreciation of engine and pipes may be estimated at 7 to 10 per cent, and if repairs are considered, the higher figure should be taken. Interest charges are high in Florida, and should not be put under 7 per cent. Thus, if a plant cost $300 per acre, including entire system and well, the annual interest charges would be $21, depreciation about $30, and operating expenses, not including labor, about $5, or a total of $56 per acre. Thus it is seen that in order to come out even on his investment the farmer must make $56 per acre more on his irrigated crop than he would if the crop were unirrigated; and he must do this every year, as it will cost nearly as much to keep the plant during a rainy season as during a dry one, since only operating expenses are low in a rainy season.

It was shown under the discussion of the Sanford subirrigation systems that the cost of growing some of the truck crops is very heavy, even though no irrigation is considered. This is true throughout the State. Sometimes large profits are made without irrigation, but, again, heavy losses are sustained in times of drought. This possibility of loss is what should determine the permissible cost of an irrigation plant, and most of the owners of overhead irrigation plants claim that the plants pay; some say they do not, while a large number admit that they do not know. It is easy to see,

however, that to erect an overhead system for the irrigation of most of the field crops, where a yearly profit of $50 per acre is supposed to be good, would be to lose money from the beginning. In any case, the farmer should look into his conditions carefully before irrigating, and be very sure that he can not get results from cheaper methods. In many cases he will find that he can not, but there are many cases where he can, and it should be his first duty to investigate.

THE FURROW METHOD AND OTHER SYSTEMS USED FOR IRRIGATING TRUCK.

The two systems of subirrigation already described and the several systems of overhead spray include 80 to 90 per cent of the area of irrigated truck in the State. The remainder is covered by various methods coming under the common designation of surface irrigation.

The largest area of garden crops irrigated by surface methods is in Manatee County, where it is estimated that 1,000 to 1,500 acres are irrigated in this way. A small acreage of strawberries in Hillsboro County is irrigated by surface methods. Other patches are scattered through the State, probably totaling not more than 500 acres.

The methods employed are very simple in most cases, many of the farmers running water in open ditches and letting it flow down between the rows, regulating the flow by means of a shovelful of soil at the head of the furrow. Some farmers use lengths of hose to aid the flow in the furrows, while others use light-weight pipe to convey water over the field. The objections to these systems are that they are wasteful of water, and that there is a considerable amount of labor attached to their operation. The possibilities in irrigation by the furrow method are worthy of careful consideration and doubtless it will become much more popular when better methods of distribution are employed.

IRRIGATION OF CITRUS GROVES.

The need of moisture for citrus trees was taken up to some extent under the discussion of soil tests. It was shown that the soil is commonly very dry for long periods, producing a harmful effect on the trees.

In order to determine the benefits accruing from the irrigation of citrus groves, a portable pumping plant was procured which could be taken from one grove to another. Such a plant will irrigate one or two rows in an unirrigated grove; and the difference in yield and quality of the fruit is observed later in the season. In this way exact data may be obtained which will give the farmer some foundation on which to estimate the allowable cost of applying water to the tree. No definite data have yet been obtained.

A great many orange and grapefruit growers claim that the benefits from irrigation are not worth the expense of installing and maintain-

ing a plant. On the other hand, many farmers have paid large sums for irrigation plants and seem to be well satisfied with the investment. There is, of course, room for much study of methods of applying water, amounts of water required, and proper times of application. These questions can be partly solved by the aid of the portable plant mentioned above. The question of methods of construction for both pumping machinery and distributing lines also is important, and will be taken up in detail elsewhere.

The annual growth of orange and grapefruit trees may be divided into four periods. The first period is in the spring when the blossoms appear and the young fruit forms; the second in the rainy summer months when the fruit takes on size; the third in the fall and early winter when the fruit is maturing and harvest begins; and the fourth in the dormant season, usually through the months of December and January. The winter and spring seasons also are the harvesting seasons in most sections of the State. The first period is the most critical from an irrigation standpoint, as dry weather may cause the young fruit to drop. The rains usually are abundant in the summer months and irrigation is not needed. The second dry period, which usually occurs in the fall, may do serious harm by preventing the fruit from attaining full size and color, as well as causing it to drop. This dry season occurs throughout the entire winter and spring months in some cases, as may be seen from the rainfall charts. Some orchardists believe that irrigation never should be practiced in the dormant season for fear of starting new growth too early, which may be killed by frost. Rainfall, however, is quite common through December and January and seems to do no harm unless accompanied by warm weather, which will start the young growth early even though the ground be dry. Generally speaking, it probably is well to wait until signs of new growth appear in the spring before beginning irrigation in frost areas, unless trees are in a wilty condition due to lack of moisture.

The amounts of water needed depend upon the condition of the soil at the time of irrigation, and will be discussed in connection with soil tests during irrigation.

HOSE IRRIGATION FOR CITRUS GROVES.

By far the most common practice in irrigating citrus groves is by the hose method, which may amount to a simple spraying by hand in connection with sprinkling systems, or in combination with furrow methods. There are two large groves where this form of irrigation is used in Manatee County, within a few miles of the town of Palmetto. One covers 240 acres and the other 370.

The latter property is located about 2 miles below Palmetto, which is on the Manatee River about 25 miles south of Tampa. The topog-

raphy of the grove is flat to gently rolling, the highest elevation being not more than 10 or 12 feet above sea level. The surface soil is light and sandy in some parts and a good quality of low hammock in others, the latter type being very light and porous. The soil is shallow over all the grove, there being a substratum of rock or hardpan under nearly the entire grove. The depth of this substratum varies, averaging about 20 inches beneath the surface. On account of the low character of the ground the trees are grown on ridges to prevent flooding out during periods of excessive rains.

Notwithstanding the low-lying topography and the frequent need of drainage due to excessive rainfall, there often is a very serious need for irrigation. This is caused mainly by the long periods of drought, but is partly due, also, to the extreme shallowness of the soil, since the moisture absorbed by the trees can not be replenished from below on account of the layer of impervious rock.

The water supply for the irrigation of this grove is obtained from two 6-inch artesian wells. Each well is about 600 feet in depth, and when allowed to flow freely will supply about 400 gallons per minute, exerting a pressure of 7 pounds per square inch when capped. Several patches of garden vegetables scattered through the grove are watered by the wells at their natural pressure. When it is necessary to irrigate the grove this pressure is supplemented by a 2-stage horizontal pump having a capacity of 700 gallons per minute and operated by a 50-horsepower gasoline engine.

The distribution system consists of about 33 miles of iron pipe, varying from 1 inch to 6 inches. A 6-inch main delivers the water to laterals varying in size from 4 inches at the main to 1½ inches at the ends. The laterals, which run parallel to each other, are placed along every fourth row of trees, the tree rows being 25 feet apart. One-inch pipe uprights are connected to the laterals at intervals of 100 feet. The hydrants are placed under trees and stand about 2 feet above the ground on the 1-inch pipe uprights.

In connection with this system there are 50 pieces of 1-inch garden hose, each about 50 feet long, and 50 movable sprinklers, each sprinkler being attached to about 6 feet of 1-inch pipe. This pipe is sharpened at one end and has the nozzle at the other, with a hose connection about 1 foot from the bottom. When in use the sharpened end of the pipe is pushed into the ground and the apparatus is connected by hose to a convenient hydrant. The pipe thus stands upright, delivering a spray of water through the nozzle, and, in this position, may be left temporarily while other pipes are being set up.

Fifty of these nozzles are in operation when irrigation is in full force. Each nozzle is placed in the center of the square formed by four trees, the spray watering one side of each tree when in a single

position. The sprays when running under a pressure of about 40 pounds per square inch will each deliver 12 to 15 gallons per minute. Each nozzle is allowed to remain in one position about 20 minutes, which means an operation of about 80 minutes for each tree, as four set-ups of one nozzle usually are required to complete the irrigation of one tree. This amounts to about 1 inch of water over the grove. The operation of this system requires the work of six men—five in the field to move the nozzles and one at the engine.

The chief objection to this system is that it takes too long to irrigate the entire grove. When the system was completed for one-half of the grove three weeks was required to irrigate that portion of it. At this rate it would take about six weeks to irrigate the whole grove, which is much too slow for any part of Florida, and especially for the shallow soils of this section. The time might be shortened by night irrigation, but night labor is very hard to obtain. More wells and pumping units would permit faster work, and these will have to be installed before the plant can be regarded as entirely satisfactory, since it is obviously impossible to irrigate successfully 370 acres with only 700 gallons of water per minute.

The cost of the plant, exclusive of the wells, is about $35,000, or about $100 per acre. This is much lower than could be expected for a plant serving a small acreage, and would be somewhat higher, of course, if the grove could be irrigated in less time.

This type of system, as used in a large grapefruit grove near Palmetto, differs only in the spacing of the hydrants, which are 90 feet apart instead of 100 feet, and there are many systems similar to this all over the citrus section of the State, although the average irrigated grove is much smaller, probably amounting to from 10 to 20 acres. A wide variation exists also as to the size of laterals and the spacing of the hydrants. Many of the groves have a hydrant spacing of 150 feet, a 1½ or 2 inch hydrant being used, and about 75 to 100 feet of hose. The smaller groves, as a rule, are not equipped with the movable nozzles, some irrigators simply letting the water run at the foot of the tree or directing the spraying of the trees by hand while moving from place to place through the grove.

The great trouble with many of the systems described above is that the owners try to economize on size of piping and pumping outfits. Some irrigators apply insufficient quantities of water. It is very doubtful if the application of small quantities is of any material advantage, as the soil often is merely packed, which spoils the dust mulch and thus aids evaporation.

ORCHARD IRRIGATION BY AUTOMATIC-SPRINKLING SYSTEMS.

The automatic-sprinkling system also is used in orchard irrigation, both the overhead-pipe and the rotary-nozzle types being

adapted to this purpose. Although the total acreage so irrigated is not large the system has attracted considerable attention. The entire area irrigated by overhead-pipe system does not exceed 10 or 15 acres. The same method is employed as for the irrigation of truck patches, except that it is necessary to keep the pipe lines above the foliage of the trees. This is not difficult in the case of small trees but trouble is experienced when the trees are large.

By far the greater area of automatic-sprinkled groves is covered by some rotating-nozzle system. This differs from the overhead-pipe system only in minor detail. The nozzles should be kept above the trees in order that the foliage may not interfere with the discharge or the distribution of the spray. A large grove irrigated by this system is at Lucerne Park, and includes 60 acres. Water is taken from a near-by lake and forced through the pipe lines by means of a 2-stage centrifugal pump operated by a 35-horsepower gasoline engine. The main consists of a 6-inch steel pipe, with 2-inch to $\frac{3}{4}$-inch laterals running at right angles to the main every second row. The nozzles are set on uprights near a tree, standing 2 or 3 feet above its top branches. They are spaced 50 feet apart and so arranged as to form a diamond-shaped figure. When the plant was installed the trees were young, standing above the ground only a few feet, but as they attained greater height it was found necessary to add a length of pipe to the uprights. The cost of the system has been high, that for the first 10 acres totaling over $500 per acre, although it was estimated that the entire 60 acres could be put in for about $250 per acre.

When this type of system is in good order it is difficult to find an easier way to irrigate a grove. No labor is attached to the process other than starting the engine and manipulating a few valves. In the grove at Lucerne Park the system will water 5 acres at one time, applying an inch of water in about 4 hours. Thus, if the plant were run continuously for 48 hours, the entire 60 acres could be covered to a depth of 1 inch, the water being diverted from one 5-acre unit to another once every 4 hours. Other advantages also are claimed, one being that it will wash off the red spider, a mite which does considerable harm to the tree in dry weather. A good washing will drive away this pest, but this may be accomplished cheaply by the use of any of several insecticides which are applied easily with any good spraying machine. Some believe that this system will prove a good protector against frost, although this claim is disputed. In any event it would be hard to keep a 60-acre grove constantly watered with a 5-acre unit. There are certain designs of apparatus which will turn water automatically very rapidly from one unit to another, but these require a peculiar method of laying out the lines and are not in actual practice so far as the writer is informed.

Nevertheless, there are disavantages to this system, the most serious perhaps being the first cost, which is too high for the average grower to consider. Inasmuch as the citrus trees in Florida grow very tall after reaching the age of about 20 years, another objection is the trouble experienced from nozzles when it becomes necessary to elevate them above the reach of the hand. This is a considerable drawback since the nozzles are likely to need attention as they become worn or clogged. An irrigation system should be put in with the idea of having permanent effectiveness, for it seems that the older a tree the more water it needs.

IRRIGATION OF GROVES BY SURFACE METHODS.

To one who has seen the systems employed for the irrigation of orange groves in southern California, it is somewhat surprising that the California methods are not in more general use in Florida, as many of the growers had visited the western systems before they installed these entirely different systems in their own groves. The furrow systems of the West are not more widely used in Florida, however, because of the difference in soil conditions, the conclusion having been that the loose and sandy soils of Florida would not permit the running of water for long distances upon the surface of the ground. Yet some prominent growers in Florida have irrigated their groves by this method with reported success. Probably the best-known grove where this method has succeeded in spite of sandy soil is a grove on Lake Butler, about 10 miles west of Orlando. The manager of the grove reported to the Florida Horticultural Society in 1907 that he had used the furrow system with success during the protracted drought of that season, running water down furrows 500 to 600 feet, and that he was using successfully a main of 10-inch terra-cotta pipe as well as several hundred feet of light portable galvanized sheet-iron pipe. The latter may be carried easily from place to place and may be made to carry water where the grades do not permit running it in furrows.

Another example of furrow irrigation in Florida is a grove at Winter Haven. The plant consists of a steam duplex pump, capacity about 200 gallons per minute, operated by a 30-horsepower engine. The main pipe line runs from the lake to the center of the 50-acre grove. Outlets consisting of 5 by 3 inch iron crosses are provided on the main, 125 feet apart. The 3-inch outlets face at right angles to the main, each being provided with a 3-inch iron gate valve. In connection with the above there is enough 3-inch iron pipe to reach from the main to the outside of the grove. This pipe is carried from place to place as it is needed.

Before the water is turned on the land several furrows are plowed in each space between the tree rows parallel to the main, and

others are plowed at right angles to these. When irrigation is begun, the men start at the far end of the main line, connecting a length of the 3-inch pipe to one of the valves and lightly screwing enough 3-inch pipe together to reach the edge of the grove. The water is then turned on in furrows prepared previously. When it has run down a furrow about 125 feet it is stopped and made to flood the trees from the lower end up toward the pipe. When the trees have been well watered other lengths are unscrewed from the 3-inch pipe and the operation is repeated. When the top end of the grove is watered the same operation is repeated from the next hydrant on the main, which is situated 125 feet below.

This method of irrigation has been satisfactory and seems to please the owner. Light portable pipe made of about 24-gauge galvanized iron 6 inches in diameter, instead of the 3-inch screw pipe, would have been more satisfactory, the iron screw pipe being heavy to shift. The cost of the plant is very low, but can not be stated exactly, as the material was purchased secondhand; but such a system of all new piping would be very cheap, compared with the systems in general use in Florida.

A number of the systems in operation in Florida may be termed partial furrow systems. Some of these have distributing systems similar to the hose systems already described, using hose to run the water down short furrows. Most of these, however, are supplied with heads of water too small to bring good results.

In some instances the water is distributed over the grove entirely by means of portable pipe, there being no permanent mains whatever. A notable example of this is in a grove near St. Petersburg, Fla. The plant waters 21 acres of full-grown orange and grapefruit trees, some of which are over 30 years old and of enormous size. The soil is exceedingly loose and sandy, probably as porous as any of the grove lands in the State. The water supply is obtained from a deep bored well 8 inches in diameter and located in the highest part of the orchard. The water rises in the well to within about 50 feet of the surface. An impeller pump is used to lift the water from the well to the surface. This pump has a capacity of about 700 gallons per minute and is operated by a 50-horsepower kerosene engine. The distributing system consists of 1,000 feet of 9-inch portable pipe of 24-gauge galvanized sheet iron in 10-foot lengths, constructed with taper ends so that one joint will fit into another like lengths of stovepipe. No other pipe of any kind is connected with the distributing system.

The operation of this system is very simple, requiring the labor of only one man. The furrows are run down grade, three being made at one time by a contrivance devised by the owner of the grove. Other furrows run at right angles to these. When water is turned

on, the portable pipe is connected by pushing the joints together, and through it the water is transported to any desired part of the grove. The furrows carry the water some distance, which reduces somewhat the labor necessary in transferring the lengths of pipe. The work is hard and requires some experience and judgment, but the results are highly satisfactory and the plant is cheap and durable. The pipe costs 20 cents per foot, or $200 for the entire distributing system, which is less than $10 per acre. The cost of the well, pump, and engine was very high, on account of the difficulty of drawing water from a bored well where the water level stands 50 feet below the surface of the ground. Construction of a pump pit was difficult, as the sandy soil extends to great depths. If this place bordered on a lake, as do many of the Florida groves, the total cost per acre would have been light.

IRRIGATION OF GROVES FROM FLOWING WELLS BY THE SURFACE METHOD.

The method of irrigation from flowing wells, as practiced extensively in Lee County around Fort Myers, is cheap and efficient. The groves irrigated by the free flow of water from artesian wells are necessarily on the lower lands, as flowing wells are not obtained on the higher elevations in the State, and, as a rule, can not be expected above the 50 to 60 foot contour. (The highest elevation in Florida is about 275 feet above sea level.) The ground surface in the Fort Myers flowing-well area is mostly level, nearly all the groves requiring drainage during the rainy season. The trees usually are grown on ridges or embankments of earth in order to keep them above standing water in times of heavy rainfall. The depressions between the rows also act as drainage ditches to carry off any excess water.

The average depth of wells here is about 500 feet. Some have a strong flow and exert a pressure as high as 20 pounds at the well when capped. The cost of wells depends on the size and depth and varies from $500 to $1,000. The average well in most groves will water 20 to 40 acres. Some of the larger groves have a number of wells in convenient locations.

Between 2,000 and 3,000 acres are irrigated by this method in Lee County. Some of the larger groves contain 100 to 500 acres, the average size of the irrigated grove being about 50 acres, most of which is in grapefruit.

Distribution of water in this section requires no particular refinement of methods, as the supply is abundant and there is no operating cost after the well is dug. For the distribution of water most of the growers use open ditches, which require no particular attention. Others run water in several furrows in each space between the tree rows, sometimes using rough wooden control gates.

These lands need water badly when the rainfall is light, as the ground dries out rapidly. Conditions here are similar to those in the Manatee section. It will be seen from the Fort Myers rainfall chart (fig. 3) that long droughts are very common, probably as much so as in any part of the State.

SUMMARY OF IRRIGATION PLANTS IN USE.

The above descriptions include all types of irrigation plants for trucking and citrus culture which are of any importance. It will be noted that all the plants are owned and operated by individuals, the irrigator owning his own water system and using it as he sees fit. He is not confronted with the water-right problems which vex the western irrigator, nor does he have to wait his turn for the water or pay irrigation district assessments. On the other hand, he has had to depend for information on men who were not experienced in irrigation methods, which often has meant poorly designed and costly plants, while his western neighbor has the advantage of the experience of previous generations of irrigators. The irrigation plants in Florida are scattered over a large territory, where the experience of one district may be of little use in another.

It will be noticed, however, that where there are uniform conditions of soil, water supply, and cropping, similar methods have been followed. This is true especially of the sections where flowing wells have been obtained. It is interesting to note that in the Sanford and Hastings trucking districts and in the Fort Myers citrus district irrigation is general, probably 90 per cent of the cultivated acreage being under irrigation. The average price of installation is low, probably less than $10 per acre for the open-ditch systems of Hastings, $20 for the Fort Myers systems, and about $125 per acre for the systems used in the Sanford district. The need for irrigation is not to be denied and should be heeded if the water can be applied without too great expense.

Leaving these areas for less favored ones where water can not be supplied at such reasonable cost, entirely different conditions will be found. Many designs of plants are in use, most of them very expensive. This is due not entirely to the lack of flowing wells, but to the fact that soil conditions will not permit the adoption of the open-ditch or subirrigation methods, and the expense attached to pumping water would not allow such wasteful methods of applying water even if the soil conditions were favorable. Instead of the cost of plants ranging from $10 to $125 per acre it varies from $100 to $500 per acre, with very few near the lower figure. Large expenditures for the irrigation of truck crops doubtless are justified in many cases, but there is some question whether this is true in the case of the groves.

It is possible that the irrigation of the Everglades will become a problem that can best be handled by cooperative methods. At present too much drainage work remains to be completed to permit the formation of any decided opinion as to the best methods to be followed. The 280 miles of drainage canals now open represent only part of the main ditches which must be constructed. Many miles of lateral farm ditches for drainage also must be constructed before the entire area can be considered as offering any possibilities as an irrigated section.

At present the region offers no problem that has not been discussed above. There are a few acres of overhead-spray systems along some of the main canals and some land has been irrigated successfully by the furrow system, water being pumped from the drainage canals. It is quite certain that pumps will be the main source of irrigation for some time. The future alone will determine the feasibility of raising the water surface by structures placed in the drainage canals, thus reversing the purpose of the farm laterals so as to use them to supply water to the farm instead of draining off the water. The Everglades are not drained, as a whole, at present, although there are a number of individual drainage projects within the main drainage system which make possible the cultivation of limited areas.

What appears to be most needed to encourage the construction and operation of irrigation plants in Florida is a knowledge of cheaper installation for the higher and sandier groves, with cheap and efficient methods of distribution. Such methods are needed in many of the truck gardens and in many of the groves that lie on the lower elevations.

EXPERIMENTS TO DETERMINE METHODS FOR ECONOMICAL IRRIGATION.

The Office of Public Roads and Rural Engineering experimented with construction for irrigation by furrow or surface methods, and to determine the distribution of water in the soil when such methods are used. The results derived from these tests have been quite uniform and point toward greatly improved irrigation systems for the future.

SOIL-MOISTURE TESTS MADE IN CONNECTION WITH IRRIGATION.

The tests in soil-moisture content were made to determine the best heads of water to use for furrow irrigation and the length of time that should be allowed for irrigation. With these points determined, the best methods for applying water could be found. The tests were made at several points near Orlando, some being in connection with the use of the portable plant mentioned on page 38 and others with larger heads from large-capacity pumping plants. Experiments were made with several types of soil, but as the closer types offer no par-

ticularly difficult problems only the results of experiments made in the sandier soils will be given.

Figure 7 shows graphically the path of the moisture in the soil. The tests were made in a grove in the sandy soils of Maitland, in the spring of 1914 when the soil was very dry. The numbers in the vertical column show the percentages of soil moisture, while the numbers at the bottom of the chart show depth in feet. For instance, the top

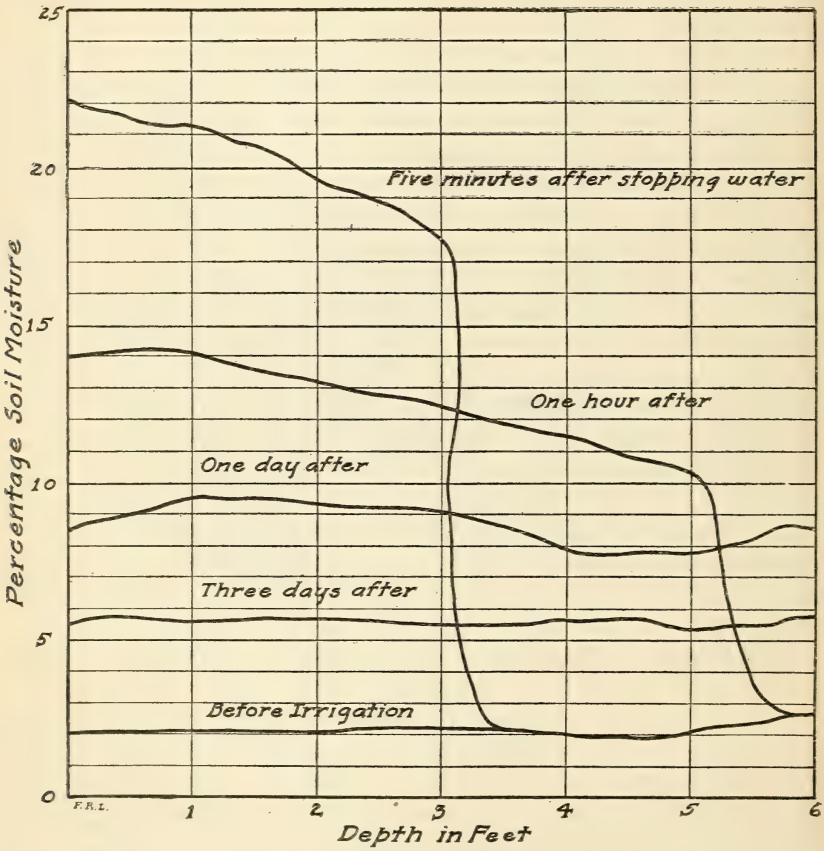

FIG. 7.—Curves showing percentages of soil moisture after running water at the rate of 70 gallons per minute in open furrows at Maitland, Fla.

curve represents the percentage of moisture 5 minutes after water had been turned off. It will be seen that there is a little over 22 per cent of moisture at the surface, about 21.3 per cent at the first foot, 19.5 per cent at the second foot, and 17.8 per cent at the third foot. The curve then drops nearly vertically and reads only 2.1 per cent at about 3.5 feet in depth, the moisture for the fourth, fifth, and sixth feet being the same as before the water was put on. Observation of the second curve taken one hour after this shows that the moisture content for the first 3 feet in depth has lowered but that the moisture

has extended to the fifth foot in depth. The other curves show the soil moisture one day and three days after, as well the the rapid disappearance of the irrigation water.

A great many interesting points are brought out by this chart, one of the most important from the irrigator's standpoint being the rapid

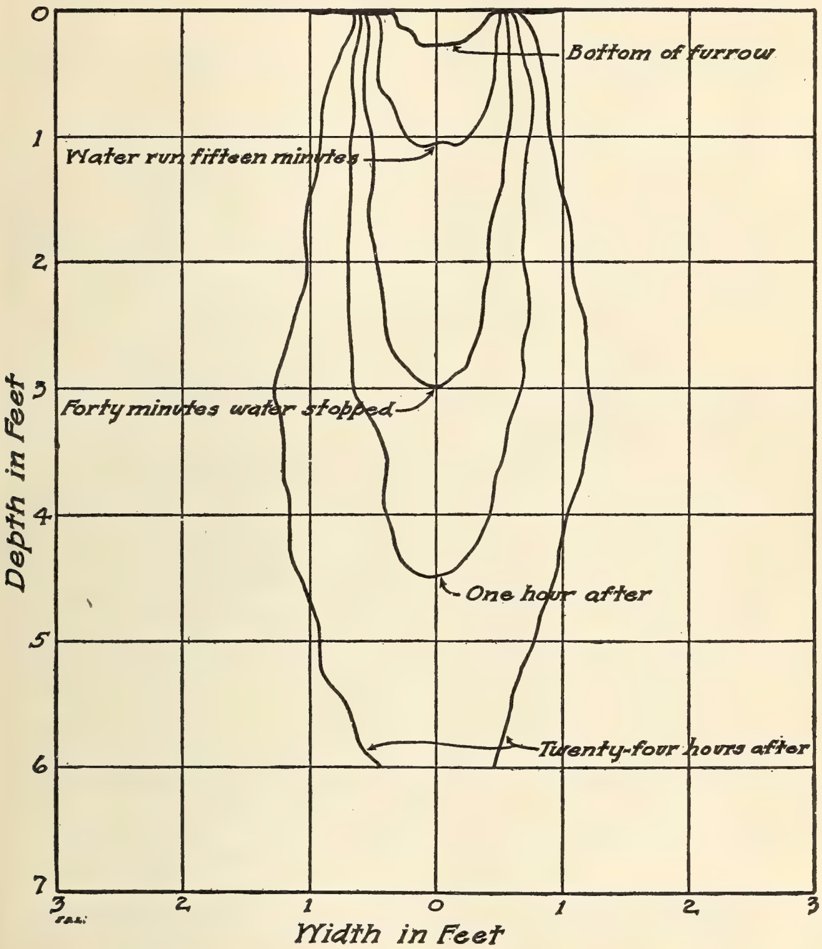

FIG. 8.—Cross section of water distribution shown in figure 7.

downward trend of the water when applied by flood or surface method. It will be noted that practically no water was lost by percolation or seepage below the sixth foot until more than an hour after the water had been turned off; after that time there was some loss. Water was run down a broad furrow at the rate of about 75 gallons per minute for 30 minutes.

Figure 8 shows a cross section of the same water distribution. In this case water was run 40 minutes over similar soil and with the

same head as that shown in figure 7. This chart does not show percentages of moisture, but does show the path of the moisture at different periods of time. The percentage of moisture can be estimated very closely from the other chart. This chart also shows that water will disappear rapidly below the sixth foot if run too long. The lateral distribution is very slight, hardly a foot on either side from

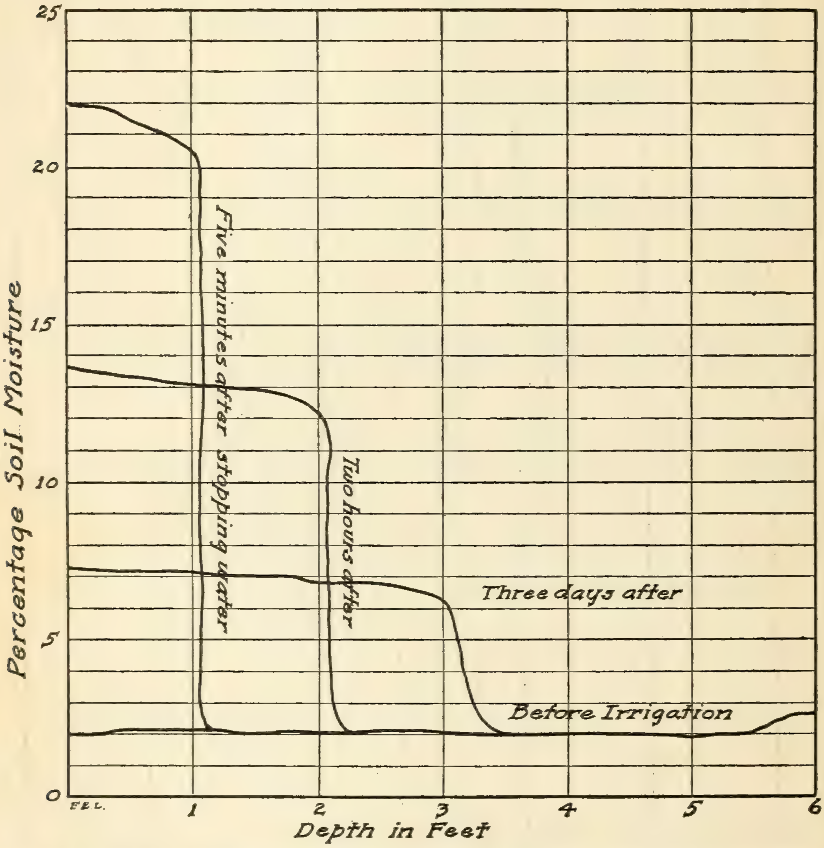

FIG. 9.—Curves showing percentages of moisture in the soil at different depths after running water at the rate of 10 gallons per minute at Maitland, Fla.

the edge of the furrow. The furrows are about a foot wide, which means that a 3-foot strip is watered from each furrow. Seventy gallons of water per minute was run down this furrow.

Figure 9 shows the same effect when water is run only 15 minutes. It will be seen that there is no waste of water below the third foot. A cross section corresponding to this curve would present an appearance similar to the one shown in chart 8, but would not extend beyond the third foot.

Figures 7 and 9 both show that before irrigation the soil was very dry all the way down, the moisture content averaging a little more than 2 per cent. In this condition this soil appears perfectly dry and could be used in an hourglass. When the moisture content reads 4 to 5 per cent the soil will hold together well when compressed in the hand, and when it contains about 10 per cent the soil is moist enough to pat to a smooth, shiny surface. At about 15 to 20 per cent water can be squeezed out. The above description will give a good idea of the state of the soil when any point of the curve is read.

Another point brought out by these tests and shown in the charts, is the distance the water will run down furrows. Tests made with different heads of water show that this distance is dependent on the head of water, provided there is some down grade to the furrows. For instance, if small heads of water were used it was found impossible to run water more than 100 feet in the grove at Maitland. Heads of 25 gallons per minute, considered large for California furrows, were useless in the sandy soils. Running the water for long periods did no appreciable good, as the water disappeared downward faster than it could be supplied; but when the heads were increased it was found that the length of furrow could be increased and that a head of about 120 gallons per minute would run a total distance of 650 feet.

The loose, sandy soils are peculiarly adapted for holding water on the surface for a considerable time when they are very dry. It is then possible to run good heads of water 600 to 700 feet. This could not be accomplished if the topsoil were moist, but as the soils usually are dry when irrigated the other condition need not be considered. The soils of many of the groves near Orlando and some near Tampa and Manatee were found to be much less porous than those of the grove at Maitland. In several of these cases small heads of water could be run long distances. Experiments in a grove at Orlando showed that heads of 25 gallons per minute were adequate for ideal furrow-irrigation methods.

It would appear from the above that if a grove is located on very sandy soils and it is desired to irrigate by furrow methods, the main concern should be to design the plant so as to supply these heads. This subject will be discussed in connection with actual construction of plants which have fulfilled such requirements.

EXPERIMENTS WITH LOW-PRESSURE PIPE SYSTEMS.

The term "low-pressure" pipe is used in this case to designate pipe that will not stand high internal pressure. Ordinary cement pipe and terra-cotta sewer pipe come under this head. Steel, cast-iron, and wrought-iron pipe will withstand high pressure without bursting.

The first experiments by the writer in Florida were made in a grove near Orlando, in 1909. The owner of the grove had set up a 25-horsepower engine and a pump which did not work satisfactorily. He was advised to install a single-stage centrifugal pump, capable of delivering about 700 gallons per minute to the highest part of the grove, about 35 feet above the surface of the lake from which the water supply was obtained. Two 5-inch wrought-steel mains carried the water to the top of the grove, a distance of about 500 feet.

The question now was how to distribute this water to the best advantage from the end of the main without expending large sums of money on iron or steel piping systems. Upon making a survey of the 40-acre grove it was found that all of it could be covered by a pipe system requiring heads of water not larger than 10 to 15 feet after the water had been pumped through iron pipe to a high point in the grove. Concrete pipe has been found satisfactory in some parts of Florida, but the poor grade of sand which had to be used discouraged its general use there. The sand was procured from Lake Weir and is considered good for ordinary concrete work, such as building blocks; but a sharp, clean sand should be selected for good concrete pipe, such as is used for irrigation purposes in the West. The principal objection to this pipe was the difficulty, with the labor available, of concreting the separate joints together so as to make them watertight. This could be accomplished in several ways, but would require special apparatus and considerable care.

Terra-cotta sewer pipe was found to answer every requirement, although care was necessary in laying it. (Pl. V, fig. 1.) The remainder of the distributing system was, therefore, finished with the terra-cotta pipe, which has given the best of satisfaction during the last six years, and judging from its use throughout both East and West it should continue satisfactory for an indefinite period.

The outlets from the terra-cotta distributing system were made by connecting special irrigation valves to short upright pieces of 6-inch terra-cotta pipe, which were connected to the main pipe by the ordinary terra-cotta T. Six, eight, and ten-inch pipes were used. These were laid in trenches on the highest ridges throughout the grove. The pipe was cemented together so as to make water-tight joints, and was then covered with earth, the top of the pipe then being at least 12 inches beneath the surface.

Probably the most important item in the construction in this grove was the arrangement to prevent excessive pressure in the terra-cotta pipe. If the iron main from the pump were connected directly to the terra-cotta pipe it is probable that the pipe would burst from water hammer, or sudden starting or stopping of the water. To prevent any possibility of this a relief standpipe was constructed at the

FIG. 1.—LAYING VITRIFIED TERRA-COTTA PIPE IN CITRUS GROVE, ORLANDO, FLA.

FIG. 2.—FURROW IRRIGATION IN CITRUS GROVE, ORLANDO, FLA.

FIG. 1.—RELIEF STANDPIPE AT CONNECTION OF IRON DISCHARGE PIPE AND TERRA-COTTA DISTRIBUTING LINES, IN ORANGE GROVE, PALATKA, FLA.

FIG. 2.—SIX-INCH CAST-IRON IRRIGATION VALVE AND HOSE CONNECTION TO SLIP-JOINT PIPE FOR IRRIGATING ORANGE GROVE, PALATKA, FLA.

point where the iron main from the pump connected with the low-pressure distributing system. This relief stand consisted of a concrete box about 4 feet square and 12 feet high, open at the top. The iron mains entered near the bottom on one side and two terra-cotta pipe lines led out near the bottom of the stand. Each of the terra-cotta outlets was fitted with a sliding gate which could be opened or closed by means of a long handle from the top of the relief stand. The top of this relief stand, or standpipe, was 3 feet above the highest elevation of the grove. If every valve in the terra-cotta lines was closed the water would rise and overflow the standpipe without exerting excessive pressure on the distribution system.

Water was distributed over the grove by diverting it into furrows, three or four furrows being placed between each two tree rows (Pl. V, fig. 2). In order to facilitate the distribution, outlet valves were placed in every tree row, and seven or eight of these were sometimes left open at the same time, thus permitting 24 to 28 furrows to be supplied with water simultaneously. Water ran 400 to 500 feet in the furrows, and only one man was needed to operate the system. The furrows were made with an ordinary sweep shovel plow.

The outlet valves installed first were similar to those used extensively in southern California for orchard irrigation, and allowed the water to escape in four or five small streams from a central stand. Trouble was experienced with these in keeping the water divided into the furrows in sandy soils; hence the above-mentioned local type, which did the work much better, was devised.

The improved valve, as designed for the experiment, is being used now for special Florida conditions on low-pressure pipe systems. It is made of cast iron and brass and is expected to stand low heads only. Its operation is very much like that of the ordinary hydrant and it may be regulated to discharge various amounts of water. The ordinary 6-inch size is made with either one or two outlets. The two-opening valve is used when furrow irrigation is practiced, while the one-opening valve is used in connection with portable slip-joint pipe. One-opening valves can be connected to two-opening, or vice versa, at any time by substituting a change of body. Ordinary 6-inch gate valves could be used, but the expense would be prohibitive, probably averaging four to six times as much as that of the low-pressure valves. The low-pressure valve of the above type is provided with a bell end, similar to the bell end of a terra-cotta pipe section, for cementing to the 6-inch riser in the same manner that one length of terra-cotta pipe is cemented to another.

Experiments made in distributing water in the grove near Orlando by means of these valves were very satisfactory. Short lengths of

portable 4-inch pipe were attached to each outlet of the valve by a flexible clamp connection. The pipe was constructed of 26-gauge galvanized iron, made in lengths of 20 feet. Adjustable gates for letting out the water were placed in the portable pipe 3 feet apart, thus permitting any desired amount of water to be let into each furrow. This was found to be a very great improvement on the type of gate first installed, as the sandy soil would not permit a good division of the water from a central point, since the furrows tended to flood together near the valve. This is prevented by the new arrangement. Both the valves and the small sliding gates in the

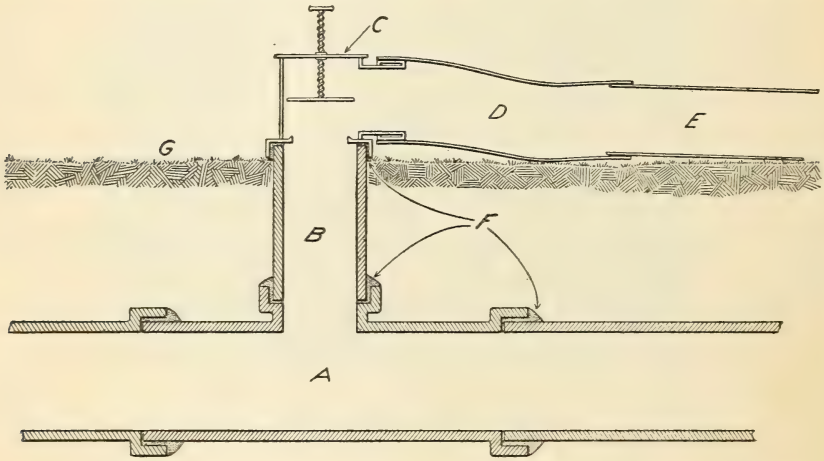

FIG. 10.—Cross section of irrigation valve, showing method of connection to underground terra-cotta main: A, Main terra-cotta pipe; B, 6-inch terra-cotta riser; C, cast-iron valve; D, connection hose; E, portable pipe; F, cemented joints; G, ground surface.

4-inch pipe have been improved, but the operating principle has been retained.

Another system involving the use of terra-cotta pipe is in operation in the grove near Palatka. This system was designed by the writer and installed in the summer of 1914. The engineer who supervised the construction has submitted the following report on the system:

The problem of efficient as well as economical irrigation, as applied to orange groves especially, has apparently been solved on the 50-acre grove at Palatka, Fla. On this project a flowing well of approximately 1,200 gallons per minute delivery furnishes the water supply, which is conveyed throughout the grove by 8-inch terra-cotta pipe. The pipe follows the contours of the highest elevations, forming a complete circle around the grove and leading back to the starting point, a standpipe near the well. (Pl. VI, fig. 1.) Six-inch low-pressure irrigation valves of cast iron are placed at intervals of 100 feet along the main line, the water being conducted to the trees by means of a slip-joint galvanized-iron pipe. (Pl. VI, fig. 2, and fig. 10.)

The plant is efficient, the water flows down the rows of trees guided somewhat by furrows and banks, and the cost of operation is practically nothing

but the cost of labor. The water supply is generous, friction being reduced greatly by the large main line.

In laying the terra-cotta pipe I met with the obstacle of inefficient labor, as there were only green negro hands available. By careful supervision, however, and by dividing the force in competitive gangs, the work was accomplished quickly and well.

As to cost, I shall give below a complete, detailed account which will show that we have put in an efficient irrigation system at the very low cost of $28.86 per acre. Very fortunately the market price on terra-cotta pipe was quite low at the time of installation.

5,000 feet No. 1 8-inch terra-cotta pipe, at $10.50	$525.00
Tees, bends, etc	25.59
500 feet 6-inch galvanized-iron, portable pipe	65.00
Reinforcing and tapering ends of same	15.00
50 6-inch cast-iron irrigation valves, at $3.50	175.00
14 barrels of cement, at $1.80	25.20
225 pounds of spun oakum	17.50
One 6-inch standard gate valve	9.75
63 feet of 6-inch black pipe (iron) and fittings	34.64
Labor of laying pipe, ditching, and erecting standpipe	250.39
Total	1,143.07

This list is complete and includes the entire outfit ready to use.

The terra-cotta pipe has many attractions for this low-pressure irrigation work. It is practically everlasting, easy to lay, and withstands the chemical action of the Florida sulphur water that ultimately destroys iron pipe. The extreme difference of elevation on this plant is 15.9 feet. The pipe stands the pressure with ease, but for a matter of precaution, in case the flow were turned on with all outlets closed, a standpipe is erected at the lower end of the line, with the elevation of the top 2 feet above the highest point in the pipe line. The water from the well flows through a 6-inch cast-iron pipe, which is the base of the standpipe. This base is of concrete in the form of a hollow square, with 8-inch pipe-line outlets. The standpipe is built of 12-inch terra-cotta pipe.

On the whole, I would say that a system such as I have briefly described is absolutely practicable and most economical as regards installation and upkeep and as efficient as any.

It will be seen from the above description that the system differs from the Orlando installation in many respects, particularly as to the method of distribution. The Palatka grove depended somewhat on the use of portable pipe, which will be used where the water can not be run by gravity. The valves are placed 100 feet apart instead of in every tree row, which means that the portable pipe will be required between the valves even where the grades are adapted to the furrow methods. These valves are the one-opening type of the 6-inch size, each capable of discharging several hundred gallons of water per minute. The terra-cotta relief stand is as good as a concrete box and much cheaper, but does not permit the installation of sliding gates as does the type used in the Orlando grove, nor does it

allow the installation of a weir for the measurement of water for experimental purposes, which is done in Orlando.

The Palatka plant could have been constructed without the portable pipe but at considerably higher cost, as the land is more uneven than that in the Orlando grove. This disadvantage might have been overcome, however, by the use of additional underground piping. It would have been necessary also to have placed a two-opening valve at every second tree row, which would have called for an additional expenditure. It will be possible to install these improvements at a later date if desired. The present system will answer the purpose well but requires more labor for its operation.

The following specifications, prepared by M. B. Williams, irrigation engineer, should be insisted upon when terra-cotta pipe is bought from dealers, as it is of the utmost importance to get the best pipe:

1. All pipe and specials shall be of the best quality standard vitrified salt-glazed terra cotta, sound and well burned, impervious to moisture, free from cracks, flaws, blisters, or other imperfections. All pipe shall be straight in the direction of the axis. Variations from a straight line greater than 2 per cent of the length of the pipe or from a true circle greater than 4 per cent of the diameter of the pipe will not be permitted.

2. Each pipe shall be of the hub-and-spigot pattern, with deep and wide sockets. Each hub shall be of sufficient diameter to receive to its full depth the spigot end of the next following pipe or special without any chipping of either and leave an annular space of not less than one-half inch all around for a mortar joint. Each hub shall have a depth from its face to the shoulder of the pipe not less than the following: 6-inch pipe, 2½ inches; 8-inch pipe, 2¾ inches; 10-inch pipe, 2¾ inches; 12-inch pipe, 3 inches; 15-inch pipe, 3 inches. The inside of the hub and the outside of the spigot of all sizes shall be grooved. All pipe shall be furnished in 3-foot lengths. All specials shall be furnished in 2-foot lengths.

3. On all T-branches the branch shall stand at right angles to the run, and have a bell or socket end.

All pipe and specials shall be delivered f. o. b. cars, and shall be subject to inspection there. Pipes or specials having fire cracks of any kind extending through the thickness and having a length greater than the depth of the hub or socket shall be rejected. Air checks appearing only on the outer surface or in the glaze of the pipe will not be objectionable, but the use of a pipe having air cracks extending through the shell caused by too rapid cooling, will not be accepted. No pipe shall be accepted that has a piece broken from the spigot end longer than the hub or socket; nor which has a piece broken from the bell end if the fracture extends into the body of the pipe, or if such fracture can not be placed at the top of the pipe. All pipe shall give a clear-sounding ring when tested with a light stroke with a hammer.

The following specifications were prepared for laying the pipe:

All terra-cotta pipe should be laid below frost and covered with not less than 15 inches of earth. Trenches should have the following width of bottom for convenient laying and jointing of the pipe:

Size of pipe .... inches..	6	8	10	12	15
Width of ditch .... do....	20	24	28	30	34

Begin laying pipe at intake end, with socket end of the pipe pointing forward. Round out bottom of trench to fit body of pipe and cut roomy depressions for sockets and entrance of hands in making joints.

Place rope of oakum around spigot end of each pipe and shove pipe and oakum together into socket. Prevent oakum from getting between end of pipe and shoulder of socket. Oakum is used to center the spigot in the socket and prevent the mortar from working inside of the pipe line. Drive oakum against the socket shoulder with a hand tamper. Lay several hundred feet with oakum before mixing joint mortar, taking care that each joint has a complete, even, annular space for mortar.

Mix joint mortar one part of Portland cement to one part of clean, sharp, fine sand. Mix the materials dry until they have uniform color, then wet to a stiff consistency which will permit the mortar being driven into the joint with an iron hand tamper without pressing out at any point.

Place mortar in joints, using light-weight rubber mittens, tamp firmly, making sure lower side of socket is filled, trowel off mortar, making a smooth shoulder, and immediately cover joint with moist earth.

Completely fill trench before rain occurs to prevent trench filling with water and floating the pipe line.

If the above specifications are followed there will be no trouble from leaks, provided the sand and cement are of good quality and care is exercised to prevent excessive pressure on the pipe. It must be remembered that this is low-pressure pipe and the design should take this into consideration. It is a safe rule to keep the pressure head between 5 and 15 feet. There should be a relief stand at some convenient point, and if the grove to be watered is a large one, it may be necessary to have several of these.

In determining the size of terra-cotta pipe to be used it should be remembered that to obtain the same flow through a small pipe that may be obtained with one of larger size will call for increased pressure. Approximate friction factors which are sufficiently close for preliminary estimates can be found in most of the pump or pipe catalogues published by various manufacturers. The following may be taken as an example: The friction of 500 gallons per minute through an 8-inch pipe is about equal to 0.6 foot per 100 feet of length. Thus, if 1,000 feet of this pipe were laid on a level, a pressure equal to 6 feet of head would be required to force the 500 gallons through the line. This would call for a pressure equivalent to a column of water 6 feet high at the intake of the pipe. An extra head of 3 to 5 feet should then be added to force delivery of the water. The factors of length and elevation must be considered carefully, and the services of an engineer should be obtained before the sizes of pipe to be used are finally decided upon. As a rule, nothing smaller than the following sizes of terra-cotta pipe should be used for the discharges indicated:

TABLE 3.—*Size of terra-cotta pipe according to amount of discharge of water.*

Quantity of water....gallons per minute..	300	500	1,000	1,500	3,000
Size of terra-cotta pipe to use....inches..	6	8	10	12	15

If the length through which the whole amount of water is to be conveyed is more than 1,000 feet it will be well to increase the size of the line. It probably will be necessary to put in a few lengths of iron pipe instead of the terra-cotta whenever the head exceeds 15 feet.

Other low-pressure pipe used with success in Florida is of the continuous concrete type. A grove in Terra Ceia is equipped with a system of this design which irrigates about 60 acres, and there is a plant of like design and capacity at Dunedin. This does not take the place of the terra-cotta pipe, however, as it is not made in sizes over 3 inches, and a 3-inch pipe is of little utility with the furrow methods considered above. Continuous pipe has, however, given excellent results when used in connection with artesian wells at Terra Ceia and with iron pipe and sprinklers at Dunedin.

Prices of terra-cotta pipe vary, but the average is about as follows, delivery being to central Florida:

TABLE 4.—*Prices of terra-cotta pipe.*

Size ... inches..	6	8	10	12
Price per foot ... cents..	10	15	19	25

Only a general idea as to total costs may be obtained by these prices.

The cost of laying the pipe also varies greatly, depending on labor and materials, soil conditions, and sizes laid, but will average from 2 to 5 cents per foot.

The complete cost of a distribution system of this type will vary for the average grove from $20 to $50 per acre, the average probably being about $35 per acre. This does not include the pumping outfit or the iron main to the standpipe. Even if the higher figure is taken it will be seen that a great saving is made on the cost of the average distribution system now in use upon the sandy groves where the iron pipe and hose systems are in use. The average cost of the latter systems probably is $100 to $150 per acre, and many of them deliver no more than a fraction of the quantities of water required.

SOME IMPORTANT POINTS IN THE DESIGN AND EQUIPMENT OF AN IRRIGATION PLANT.

The first consideration for prospective irrigators is the water supply. Practically every section of Florida can be watered easily either from wells or from lakes or streams. Estimates as to the size and probable depth of a well should be obtained from local well drillers or from the State geologist, as conditions vary greatly. The cost of a well will depend mainly on its size and depth.

The area to be irrigated is the next item to consider, this and the capacity of the water supply being the determining factors in the

size and capacity of the pumping unit. The crop to be raised also must be taken into account, as must the methods which will be employed in distributing water. If the water supply is adequate and a 100-acre grove is to be irrigated it is evident that the plant should be of such capacity as to irrigate the whole grove within a reasonable time in order to obtain maximum service from the plant. This is true also for the 10-acre grove or the 1-acre truck patch. For the irrigation of a grove the surface methods probably would prove most satisfactory, and an irrigation equivalent to not less than two inches of rain should be figured on. A truck patch should have about the same amount for furrow irrigation, and about one-half of this if spray methods are employed. Another important factor to be considered in determining the necessary capacity of the plant is the time the farmer desires to consume in watering the grove. If he is willing to irrigate 24 hours a day he can get along on half the amount of water needed per minute in a day half as long. But night irrigation by surface methods seems to be unpopular in Florida and it will be best to figure on a 12-hour irrigation day. The personal element also enters into the number of days of irrigation required to cover the grove, but it is doubtful if a plant can be considered efficient if it will not furnish enough water to cover the grove in 10 days. This period is a good standard for use in Florida.

If 2 inches of water is to be applied to a 100-acre grove in 10 days of 12 hours each, the problem of figuring the gallons per minute is a simple arithmetical one; and this is equally true whether the grove contains 52 acres or 7 acres. There are 27,154 gallons in an acre-inch. Considering loss in transmitting and other losses while irrigating, it is better and easier to say that it requires 30,000 gallons of water to cover 1 acre 1 inch deep, or 60,000 gallons 2 inches deep. In the 100-acre grove it is necessary to apply 200 acre-inches, or 6,000,000 gallons of water. If this is done in 10 days, or 120 hours, or 7,200 minutes, a pump having a discharge of $\frac{6,000,000}{7,200}$, or 833 gallons per minute, will meet requirements. For any other acreage, gallons divided by minutes will give the capacity of the pump per minute.

Two acre-inches of water would answer for the furrow-irrigated patch if diversified truck crops which did not all need water at the same time were grown, but as the truck crops require a more rapid irrigation than the grove, owing to earlier injury from drought, it is well to double this estimate where such crops are to be watered. Irrigation by spray methods brings in other problems which can be solved readily, although they are of a different nature from those just discussed. For the spray plant it is advisable to figure on a

capacity equivalent to about 1 inch of rainfall per week for the entire area when the plant is running 5 to 8 hours per day.

Two general types of pumps are used in irrgation—high-pressure and low-pressure. The former are used in Florida for such plants as those using the high pressure overhead-spray systems and for many of the hose systems. The low-pressure systems, as a rule, are not used for exerting pressure over 20 to 30 pounds per square inch, but are employed extensively for irrigation purposes throughout the West and are the best design of pump for most surface methods as used in Florida.

The designs of pumps are innumerable, but two general types, the centrifugal and the displacement pumps, are most adaptable to Florida conditions. The centrifugal pump consists of a circular shell which incloses a swiftly rotating impeller. The water enters at the center of this impeller and is forced by the velocity imparted to the water by the curved fans of the impeller out of a discharge pipe leading from the outer edge of the shell. In Florida these pumps are used in the one-stage (having one impeller) and two-stage (having two impellers) types. The single-stage pump is built in sizes to lift any quantity of water to 75 to 125 feet. The two-stage pump will lift twice as high as a single stage. The single-stage pump is used for low-pressure work on surface systems and some spray systems of irrigation. The two-stage pump is used on several spray systems where the total head exceeds 75 feet.

Centrifugal pumps are, in general, most adaptable for pumping large quantities of water with the smallest installation cost. The efficiencies range from 30 to 65 per cent. They are built in many different forms to fit different water supplies, including wells. They are light in weight, require small space, seldom need repairing, have no valves, and are injured but little by grit in the water. These pumps should be placed as close to the water as possible and never exceed a suction lift of 25 feet. All air must be expelled from the pump case and suction pipe and these must be filled with water before starting. The speed must be proportional to the lift and quantity of water to be pumped.

Low-pressure centrifugal pumps range in cost from 1 cent to 5 cents per gallon per minute capacity. High-pressure pumps range from 5 cents to $1.25 per gallon per minute capacity. The smaller the pump the higher the rate of cost per unit of capacity.

Displacement pumps lift water by means of a close-fitting plunger or piston traveling backward and forward in a cylinder equipped with valved openings. The best known displacement pump in Florida is the small, single-acting piston type used for domestic purposes, commonly called the pitcher pump, and usually operated by

hand. This type of pump is made with one (simplex), two (duplex), and three (triplex) cylinders. They are built to fit any type of water supply and in sizes to deliver any quantity of water for both high and low pressure. All three types mentioned are used in Florida with satisfaction. Displacement pumps are more costly than the centrifugal pumps, ranging from $1 to $4 per gallon per minute capacity, but the smaller sizes are much more efficient in many cases. These pumps range in efficiency from 50 to 75 per cent, but wear rapidly if there is grit in the water and need more adjusting and attention than centrifugal pumps to maintain their efficiency.

Practically the only types of power available in Florida are steam, gas, or oil. Gasoline or kerosene engines will be chosen in most cases, steam engines being used only where wood is cheap and the engine can be bought at a reasonable price. Electrical power in Florida is too expensive for use at the present time. The use of windmills is also impracticable for an area greater than a half acre, since a windmill requires the construction of a reservoir for irrigation purposes and a reservoir of sufficient size is more costly than a good pumping plant. Windmills are used for irrigation in the West, but soil conditions there permit the construction of cheap earth reservoirs, which is not the case in Florida. Current wheels and water wheels need not be considered here, as their use in the State is practically negligible.

The design of a pumping plant should not be undertaken by anyone unfamiliar with the technical factors entering into each case. The most certain method for a farmer to follow in obtaining a well-designed plant is to employ an engineer to make a survey and determine these factors, which should be submitted to several pump and engine dealers for their proposals. The proposals then can be compared and the most adaptable plant selected. The principal factors which the engineer should determine may be listed as follows:

1. The capacity and character of the water supply.
2. The kind of power to be used.
3. A description of the pumping site.
4. The type of distribution system to be installed and the pressure necessary to operate same.
5. The amount of water to be pumped per minute.
6. The elevation of the highest point of land above the water level when the pumping plant is running.
7. The length, type, and size of main pipe leading from the water supply to the point in the field where the water is to be delivered to the distribution system.

It is well to place these factors in the form of simple specifications and call for full descriptions and guarantees of the machinery proposed to be furnished, with prices quoted on the materials delivered at the nearest railroad station.

In conclusion, it has been seen that iron pipe is used in most distributing systems in Florida, but that this is often subject to rapid rusting. It is also expensive if large sizes are used, and if small sizes are used the plant is apt to be inefficient. It is not possible to avoid the use of iron or steel pipe for most of the spray systems, but the use of galvanized steel or galvanized iron pipe is advised for all overhead lines. If a low-pressure system is used for surface irrigation, it is practically necessary to have a high-pressure main pipe connect the pumping plant to the relief stand. This may be either cast-iron, wrought-iron, steel, or riveted steel pipe (black or galvanized). The cost of such pipe varies greatly, the cast-iron type being the most expensive but the most durable for Florida conditions. The riveted-steel pipe is cheapest, and will serve for a long time if well galvanized. It is probably unwise to install the asphalted or black riveted steel, as Florida conditions are very hard on such pipe.

A great deal of pipe has been taken up which has rusted out entirely in a few years. One experienced man reports that the lasting qualities of cast-iron, wrought-iron, and steel pipe are about in the ratio of five to three to one.

The size of the main will depend upon its length and the quantity of water it must deliver per minute. Most of the pumping plants in Florida will not need a main of more than 1,000 feet. For such conditions it would be well to keep within the following pipe sizes:

TABLE 5.—*Size of pipe required according to quantity of water to be delivered.*

Capacity..............gallons per minute..	10	30	100	250	300	450	600	1,000	1,500
Size of pipe..........................inches..	1	2	3	4	5	6	7	8	10

If smaller sizes are used for the corresponding capacities it will be necessary to increase the horsepower very materially to deliver the required quantity of water.

Finally, it will be seen that the saving effected by the installation of low-pressure pipe for furrow irrigation means not only a great saving in the distribution system but also a saving in the pumping outfit, on account of the reduced friction in the pipe system. If the power is not increased to compensate for the smaller pipe systems, the result is a diminution of the quantity of water to be delivered and a corresponding interference with the whole purpose of erecting and operating the irrigation plant, which is, of course, the delivery of sufficient water to prevent loss from the lack of moisture in the soil.